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Summary Report, Risk Assessment Modeling Workshop

14-15 May 1998, New Orleans, Louisiana

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Environmental Laboratory

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Contents

Preface

The work reported herein was conducted by the U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Vicksburg, MS, for Headquarters, U.S. Army Corps of Engineers (HQUSACE). Funding was provided by the HQUSACE Installation Restoration Research program (IRRP), Fate & Effects Thrust Area, Work Unit entitled Risked-Based Cleanup Decision Support/Assessment System-Remediation Assessment Modeling System (RAMS). Dr. Clem Myer was the IRRP Coordinator at the Directorate of Research and Development, HQUSACE. The IRRP Program Manager was Dr. M. John Cullinane, EL.

This report was prepared by Drs. Patrick N. Deliman and Carlos E. Ruiz, Water Quality and Contaminant Modeling Branch (WQCMB), Environmental Processes and Effects Division (EPED), EL, and Mr. Jeffrey A. Gerald, AScI Corporation, McLean, VA. Ms. Lillian Schneider and Dr. Christian J. McGrath, WQCMB, EL, were technical reviewers for this report.

The work was conducted under the general supervision of Dr. Mark S. Dortch, Chief, WQCMB, Dr. Richard E. Price, Chief, EPED, and Dr. John W. Keeley, Acting Director, EL.

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1 Introduction

Background

The Fate & Effects Advisory Committee (FEAC) identified the need for the development of models capable of providing information relating to the fate and effects of Military Relevant Compounds (MRCs) on both ecological and human resources. Stated was the requirement for better modeling capabilities of contaminant concentration over time for risk assessment. In an effort to address the requirement, a work unit was initiated for the development of an Army Risk Assessment Modeling System (ARAMS). This system will incorporate other research efforts conducted in the Fate & Effects research program and will enable thorough evaluation of ecological and human risk assessments.

The ARAMS will be developed for the purpose of conducting ecological and human risk assessments. Development of this system will incorporate current state-of-the-art modeling technologies and will further utilize concurrent research efforts in the Fate and Effects Research Program. The ARAMS is a tool to characterize, integrate, and estimate ecological risk. The system will provide several tiers of complexity such that screening level and complex models issues can be addressed. The system will include: (a) screening level assessments based on simple exposure-response relationships and limited spatial and temporal scales, (b) an expanded assessment capability based on linkage of more rigorous exposure and ecological assessment techniques and (c) linkage of ecological risk, comprehensive exposure models, and integrated temporal-spatial exposure,..i.e., probabilistic estimate of exposure for individuals/population in time and space.

Objective

The objective of this workshop was to ascertain the current state-of-the-art in risk assessment modeling and to facilitate discussion of the components required for an ARAMS.

Presentations

The presentation topics at the workshop were selected to provide a foundation for the discussion of the development of ARAMS. Each topic was considered to be a potential building block for the conceptualization of the system. The topics presented were: Ecological Risk Assessment Concepts; A WEB-Based Approach for Developing Risk Assessment Modeling System; The Groundwater Modeling System; The Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES); Dredged Material Modeling—Risk-Based Concepts, Bioaccumulation Modeling Concepts, and Principles/Contemporary Issues; Ecosystem Models for Ecological Risk Analysis: Single Species to Communities; You Don't Need to Know a Lot of Ecology to Make a Comprehensive Ecological Risk Assessment; Risk Analysis of Potentially Contaminated Sites Using the U.S. Environmental Protection Agency (EPA) MMSOILS Multimedia Model; Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity; Ecological Risk in an Integrated Intermedia System, and Exposure Assessment - Trophic Transfer to Birds. A brief description of the topics presented at the workshop follow. Appendix A presents the "Conference Agenda and List of Participants." Copies of the actual presentation documents from each speaker at the workshop are shown in Appendixes B through K with the exception of "A WEB-Based Approach for Developing Risk Assessment Modeling System" and "The Groundwater Modeling System." Hard copy versions of these two presentations were not available.

Ecological risk assessment concepts

Ecological risk assessment modeling may be broken down into four areas of interest: (1) problem formulation, (2) exposure assessment, (3) effects assessment, and (4) risk characterization. The Department of Defense (DoD) has historically emphasized human health protection, but ecological concerns are becoming more prominent.

An ecological risk assessment survey of 190 Army facilities indicated that more than 50 percent were/anticipated conducting ecological risk assessments. DoD risk assessment needs include (a) modeling/software tools for risk characterization, (b) modeling/software tools for projecting effects beyond individual organisms, (c) modeling/software tools for incorporating spatial and temporal issues when assessing risk, and (d) modeling/software tools for quantifying uncertainties.

WEB-based approach for developing risk assessment modeling system

A web-based approach was presented to demonstrate the utility of updating and maintaining databases via the Internet. The newly developed Land

Management System (LMS) was given as an example. This system contains components of the Watershed Modeling System (WMS), and a demonstration of was presented showing how the CASC2D hydrologic model within the WMS could be initialized and run across the Internet. The United States Geological Survey's (USGS) topographical databases were accessed and dowloaded incorporating the WEB-based approach. This downloaded information could then be used to setup the grid structure for the CASC2D model. A previously developed CASC2D model application was then run (in an effort to save time) from a remote access site to display the features of incorporating offsite computing resources for conducting modeling runs or scenarios.

Groundwater modeling system

The Groundwater Modeling System (GMS) was developed by the DoD in partnership with the Department of Energy, the U.S. Environmental Protection Agency, Cray Research, and 20 academic partners. The GMS provides an integrated and comprehensive computational environment for simulating subsurface flow, contaminant fate/transport, and the effectiveness of remediation design alternatives.

GMS integrates and simplifies the process of groundwater flow and transport modeling by bringing together all of the tools needed to complete a successful study including both pre- and postprocessing tools. GMS provides a comprehensive graphical environment for numerical modeling, tools for characterization, model conceptualization, mesh and grid generation, geostatistics, and sophisticated tools for graphical visualization. The system is also currently available for both PC- and UNIX-based operating systems. Several types of models are supported by GMS. The current version of GMS provides a complete interface for the codes FEMWATER/LEWASTE, MODFLOW, MODPATH, MT3D, RT3D, and SEEP2D . Anticipated model additions in the future include UTCHEM, NUFT3D, ParFlow, and ADH.

The framework for risk analysis in multimedia environmental systems (FRAMES)

FRAMES is a software platform that allows models, developed by different people, to link and communicate with each other, while maintaining the legacy of the original models. FRAMES provides several functions: (a) it allows users to implement preferred models, (b) it allows users to link preferred models to and communicate with other models, (c) it allows for a standard, base set of models (regulatory review), (d) it maintains the legacy of models, (e) it provides a "plug-and-play" environment, and (f) it helps the user with the conceptual site model. The traditional multimedia modeling approach involves thinking in the abstract with complex flow charts for inputs, transport pathways, exposure routes and outputs, but FRAMES offers a nontraditional approach which offers the multimedia modeler the capability to conceptually build the system to be modeled through a graphical user interface (GUI) and drag and drop modules.

The modules communicate to other modules through the use of data processors and a data standard specification which is built into the FRAMES user interface.

Dredged material modeling—Risk-based concepts

Technical evaluation of the environmental acceptability of dredged material disposal is an effects-based process compatible with risk assessment. Computer programs and databases have been developed to aid in the evaluation and include the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) and the Environmental Effects Determination Database (E2D2). ADDAMS) is a PC-based system for DOS and Windows 95. It is a collection of 16 modules which are simple, nonintegrated, computerized tools and models for dredged material management and environmental effects evaluation. The modules in ADDAMS are predominantly stand-alone screening-level models linked under a common shell or menu. E2D2 is a web-based database of literature on environmental effects of contaminant residue in tissue of aquatic organisms. It provides for the interpretation of bioaccumulation data to determine environmental significance in absence of criteria.

Bioaccumulation modeling concepts and principles/contemporary issues

The allowable dose for any animal anywhere in an aquatic system is the intake from water ingested plus the intake from food/prey ingestion. We can define the bioconcentration factor (BCF) as the ratio of chemical contaminant in food-to-water concentration for exposure to water only. The major advantages of this are (a) that the BCF is easily determined in the laboratory under controlled conditions with "standard" (small) fish and (b) it is not dependent on site characteristics. This method allows for a neat and clean, site-independent national water quality criterion (WQC). If a WQC is used that is based on a bioaccumulation factor (BAF) which is dependent on the food web, a not-so-neat-and-clean method results. This method is site dependent and makes a national WQC possible only for a generic food web.

How do you determine the allowable waste load allocation of chemicals that may bioaccumulate? The proposed approach is to regulate on allowable tissue concentration at assigned frequency of exceedance percentile and to determine the allowable frequency distribution of chemical input load.

Ecosystem models for ecological risk analysis: Single species to communities

To justify regulatory and mitigation decisions, toxicologists are often asked the "so what?" questions that demand predictions about the population or even ecosystem response to contamination. Ecotoxicology is microcomputer software specifically created to help toxicologists answer such questions by extrapolating

effects on organisms observed in bioassays to their eventual population-level consequences. It provides a software shell from which users can construct their own models for projecting toxicity effects through the complex filters of demography, density dependence, and ecological interactions in food chains. It allows various standard choices about low-dose response models, which vital parameters are affected by the toxicant, the magnitudes and variabilities of these impacts, and species-specific life history descriptions. During the calculations, the software distinguishes between measurement error and stochastic variability. It forecasts the expected risks of population declines resulting from toxicity of the contaminant and provides estimates of the reliability of these expectations in the face of empirical uncertainty. This risk-analytic endpoint is a natural summary that integrates disparate impacts on biological functions over many organizational levels.

You don't need to know a lot of ecology to make a comprehensive ecological risk assessment

There are five problems which lead to lack of trust in the risk analysis: (1) tool for obstructionists, (2) help for the other side, (3) need for too much data, (4) too expensive (requires consultants), and (5) too complicated. A good uncertainty analysis can alleviate the last three problems, and even though uncertainty is often large, it may still permit clear decisions.

There are three major problems with risk analysis: (1) correlation and dependency are ignored, (2) input distributions are unknown, and (3) mathematical structure is questionable.

Correlations and dependencies in uncertainty analysis are typically based on one of the following independence assumptions: dispersive Monte Carlo sampling, or dependency bounds analysis. Dispersive Monte Carlo sampling assumes extreme correlations so the result is as broad as possible. It is also computationally cheaper than ordinary Monte Carlo methods.

The default distributions for unknown input distributions are typically maximum entropy or probability bounds (P-bounds). Maximum entropy generalizes Laplace's Principle of Insufficient Reason and yields a distribution with minimum bias and maximum uncertainty under the constraints. Probability bounds (min, max, mean, median, shape, etc.) and P-bound arithmetic are quicker than Monte Carlo and are guaranteed to bound answer and provide the optimal solutions in most cases.

A questionable mathematical structure can be made more sound by incorporating a comprehensive battery of checks and incorporating model uncertainty into the analysis. The battery checks should provide general checks (e.g., dimensional and unit concordance) and checks against domain knowledge (e.g., population size nonnegative). The advantages of P-bounds as the uncertainty tool are: (a) much faster than second-order Monte Carlo, (b) easy (graphical) parameterization, (c) handles uncertainty about parameter values,

distribution shapes, dependence and correlation among variables, even the form of the model itself, and (d) faithful to most frequent interpretation.

Risk analysis of potentially contaminated sites using EPA's MMSOILS multimedia model

The purpose of this presentation is to provide an introduction to the MMSOILS model, its uses and limitations, and to demonstrate how MMSOILS was used in one EPA program, Hazardous Waste Identification Rule (HWIR), to provide an initial assessment of many sites. Some selected features of MMSOILS multimedia model are

a. Contaminant transformation and fate processes

b. Intermedia contaminant fluxes

c. Exposure pathways

d. Human health risk measures

e. Media-specific transport.

The purpose of EPA's HWIR is to evaluate if certain low-risk wastes can be disposed of as nonhazardous. The EPA "Exit" Rule is the question : at what concentrations can specific chemicals "exit" hazardous waste disposal requirements and be protective of human health and environment? The scope of HWIR is nationwide and is specific to chemicals and waste management unit (WMU) types. HWIR specifies approximately 400 chemicals and WMU types of landfill, impoundments, and waste piles. EPA's approach to implementing HWIR is through a multimedia/multipathway, risk-based(human health and ecological), and site-based (create plausible sites and assume each chemical could be disposed at each site) methodology.

Factors that influence computational effort to implement HWIR are: (a) there can be hundreds of sites, (b) five to six source types, (c) 400 plus chemicals, (d) the range of source concentrations, and (e) Monte Carlo loops. The computational burden on a computer processing unit (CPU) to implement a modeling scenario can easily approach centuries when Monte Carlo uncertainty is used. Means to reduce computational burdens, such as making use of linearity, grouping of chemicals, risky versus nonrisky sites, and minimizing the number of random variables are required.

Metapopulation models and ecological risk analysis: A habitat-based approach to biodiversity

Metapopulation dynamics are important in ecological risk analysis, and modelers ignore spatial structure at their own risk. Spatially explicit

metapopulation models provide practical compromise between complexity and applicability. Future directions for ecological risk analysis modeling will be to incorporate habitat relationships, involve multispecies approaches, and allow metapopulations in trophic chains. Metapopulation models are important because they allow assessment of impacts, evaluate management options at the metapopulation level, and also allow complicated population dynamics to be simulated.

Factors that affect population dynamics are:

a . Demography: survival, fecundity, and growth.

b. Age or stage of structure.

c. Density dependence.

d. Environmental fluctuations, catastrophes.

e. Demographic stochasticity.

Factors that affect metapopulation dynamics include all of the ones for population dynamics, but additionally include:

a. Number of populations.

b. Geographic configuration.

c. Spatial correlation.

d. Migration patterns.

The occupancy metapopulation model has the advantages of analytical solution and generalizations. It has disadvantages of unrealistic assumptions, difficult parameters, and few or infinitely many patches. The spatially explicit metapopulation model has the advantages of being flexibile and realistic with few implicit assumptions. Its disadvantages are that it is data intensive, difficult to add genetics, and numerical errors may occur. The individual-based metapopulation model has the advantage of being very flexible and realistic. Its disadvantages are that it is easy to make numerical and/or logical errors, is very data intensive, and is sensitive to behavioral assumptions.

Future directions in metapopulation modeling will be in multispecies assessments and in developing community-metapopulation models. In community-metapopulation models, each trophic level would be represented as a metapopulation, each metapopulation would have a different spatial scale, and connections between metapopulations would be based on energy flow.

Ecological risk in an integrated intermedia system

Models and tools are needed to bridge the gap between source, fate, transport, and the resulting ecological impacts. A phased approach is presented for varying levels of detail to match tools to assessment needs. This approach provides for a preliminary as well as a detailed assessment.

The ecological models discussed include the Wildlife Ecological Assessment Program (WEAP), the Ecological Contaminant Exposure Model (ECEM), the Health and Ecological Risk Management and Evaluation System (HERMES), and the Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES).

The WEAP model represents a preliminary assessment to ecological risk analysis. It correlates exposure and effect using laboratory data. It analyzes and correlates concentration and duration of exposure. The model also accounts for frequency of occurrence.

The ECEM model is an ecological risk assessment modeling tool. It estimates exposures from metals, organics, and/or radionuclides in terrestrial and/or aquatic environments. The model is based on a food-web architecture and helps environmental managers assess impacts as part of a regulatory or decision-making process. User inputs for the model are:

a. Contaminants of interest.

b. Species of interest and species in the food web.

c. Environmental data.

Results of the model are:

a. Body burden or dose rate.

b. Compared to environmental benchmarks to calculate the environmental hazard quotient.

c. Can be used as input into human health assessments.

The HERMES model is a flexible visualization and analysis program which helps environmental restoration, land use, and resource managers make decisions. It allows interactive evaluation of impacts with user-selected restoration costs and species values. Other decision dimensions, such as human health, ecological risk, and ecosystem function, can be included as extensions to the model. The advantages of the HERMES model are:

a. Usable - links with user's existing databases.

b. Portable - can be run on a laptop computer, which facilitates public involvement.

c. Easily manipulated - user can control data input values

d. Expandable - modular design allows inclusion of additional decision dimensions.

The FRAMES user interface serves as the integrating platform for all the models discussed. It provides linkages between fate and transport, ecological, and human-health models.

Exposure assessment—Trophic transfer to birds

Why quantify trophic transfer to birds? There are four main reasons which include (1) to computing contaminant levels in species of interest (contaminant levels can be used to assess the potential for toxicity), (2) establishing pathways of contamination, (3) projecting future concentrations, and (4) establishing the potential for effects on population dynamics.

Bioaccumulation can be computed in several ways:

a. Trophic transfer ratios, bioaccumulation factors.

b. Steady-state model.

c. Time-variable simulation model.

BAFs are the simplest, but have the highest degree of uncertainty. The steady-state model is one step above the BAF with the strength of species-specific parameterization, but with the limitation of life-cycle accumulation and temporal changes in exposure sources and levels. Time-variable models have the strength that changes in relative importance of sources can be evaluated and have the limitation that it requires modeling capability and information on parameters. A calibrated model has the strength of reduced uncertainty, but the limitation of requiring site-specific data. Uncertainty analysis for calibrated and uncalibrated models differ. The calibration of a model reduces uncertainty by restricting the parameter sets that are consistent with field measurements.

Technical Issues

Prior to the workshop, a list of questions was generated to aid in focusing the discussions at the workshop. These questions along with the oral presentations provided the background for the Risk Assessment Modeling Workshop. The following questions were used to stimulate discussion at the workshop:

a. What is the state of the art in risk modeling?

b. What are the requirements for a simple- or screening-level risk assessment?

c. What are the requirements for a comprehensive risk assessment?

d. What tools are required for a risk assessment ?

(1) Exposure component.

(2) Effects component.

(3) Other potential components.

(4) Are these tools applicable for a comprehensive risk assessment, and can the tools be integrated in a common (object oriented) environment?

e. What tools are currently available?

(1) Exposure component.

(2) Effects component.

f. Should we develop tools (state-of-the-art) or incorporate existing ones?

g. Is there a need for a risk assessment modeling system/environment? This system would include gains, losses, and advancement of the current state-of-the-art.

h. What is the feasibility of developing a risk assessment modeling system (beyond the current capabilities/state of the art)? Such a system must include structure/platform and output.

i. Can/should the screening-level and comprehensive exposure models coexist in the same modeling environment?

j. Should we develop tie-ins to existing systems (GMS, Surface Modeling System (SMS), and WMS)?

k. What are the existing sources of effects/toxicity databases?

(1) Public domain.

(2) File structure (cd, web, binary, bulletin boards, etc.).

(3) Proprietary

l. What is the desired modeling platform (i.e., personal computer, work \station, web-based . . .)?

2 Summary of Discussions

Introduction

The concepts and foundation for the development of both human and ecological risk assessment have been around for several decades. Past research efforts have yielded methodologies for conducting risk assessments, including exposure and effects assessment, as well as procedures for investigating uncertainty propagation through these models. The basic premise is to calculate risk as a function of both exposure, human or ecological, and effects resulting from exposure. The effects component can be acute or chronic. Therefore, the risk assessment paradigm is typically a problem formulation leading to both an exposure and effects assessment. The combination of the exposure and effect components results in a calculated risk characterization. Risk assessments are useful planning tools for the evaluation and determination of the impact of contaminants on both human and ecological resources.

From a military perspective, the contamination to air, surface water, and groundwater from MRCs has been of increasing concern in the past several years as the result of the closing of munition plants and bases. The assessment of the exposure to ecological units from the many mediums through the use of an exposure model is required to determine the risk associated with exposure to MRCs from these media. This assessment is valuable for permitting and planning activities, as well as for the possible cleanup operations of contaminated sites, should the risk to an ecological unit become too great (Deliman and Gerald 1998).

Background

Historically, there have been several options for conducting risk assessments. Perhaps the simplest of these involves direct field measurements to estimate exposure concentrations. These direct exposure estimates are then compared to effects data to estimate a risk, i.e., a risk quotient. One problem with this method is the assumption that the exposure concentration collected at the sample site is constant, both spatially and temporally. To gain an understanding of the time or

spatial variance influence upon the estimated exposure concentration, a screening- or comprehensive-level model should be utilized.

Initially, when an indication of the level of risk associated with an exposure is desired, the use of a screening-level model will maximize the amount of information provided while minimizing the amount of effort required to obtain the necessary information to make a risk assessment. A screening-level exposure model refers to use of simplified, quantitative, predictive methods that minimize time and effort for implementation. Simplification is achieved by making assumptions that reduce the complexity of the predictive mathematical formulations and input data. If the results of the risk estimated by using screening-level exposure models indicate undesirable risk levels to either human or ecological resources, a more comprehensive exposure modeling approach should be employed. Comprehensive models being more physically based, both spatially and temporally, than the screening-level models can produce results which are more accurate and defendable. Selection of a comprehensive exposure model results in increased data and computing resource requirements.

During the workshop, the concept of the platform for the development of ARAMS was discussed. The three choices that were presented as viable alternatives were (1) personal computer-based, (2) workstation-based, and (3)web-based. Of these three, the web-based platform offered the most advantages, as well as combining the best of PC and workstation environments. The web-based system design was selected for ARAMS. The primary advantage of a web-based system is the ability to easily update and maintain databases which are required for both effect and exposure assessments. Users of ARAMS can access and search databases via the Internet by launching applets in the background. In addition, web-based systems offer the advantage of distributed computing. Distributed computing enables users without high-powered computing capabilities the option of running programs at remote locations. It is important to note that some security issues will have to be addressed for access to secure sites for some military applications.

The ARAMS will be developed for the purpose of conducting both screening- and comprehensive-level ecological risk assessments. Development of this system will incorporate current state-of-the-art modeling technologies and will further utilize concurrent research efforts in the U.S. Army Fate and Effects Research Program. The ARAMS will be a tool to characterize, integrate, and estimate ecological risk. The system will provide several tiers of complexity such that screening-level and complex models issues can be addressed. The system will include: (a) screening-level assessments based on simple exposure-response relationships and limited spatial and temporal scales, (b) an expanded assessment capability based on linkage of more rigorous exposure and ecological assessment techniques, and (c) linkage of ecological risk, comprehensive exposure models, and integrated temporal-spatial exposure, i.e., probabilistic estimate of exposure for individuals/population in time and space.

ARAMS will contain the following components: (a) screening-level models, (b) comprehensive models, (c) population models, (d) an uncertainty component,

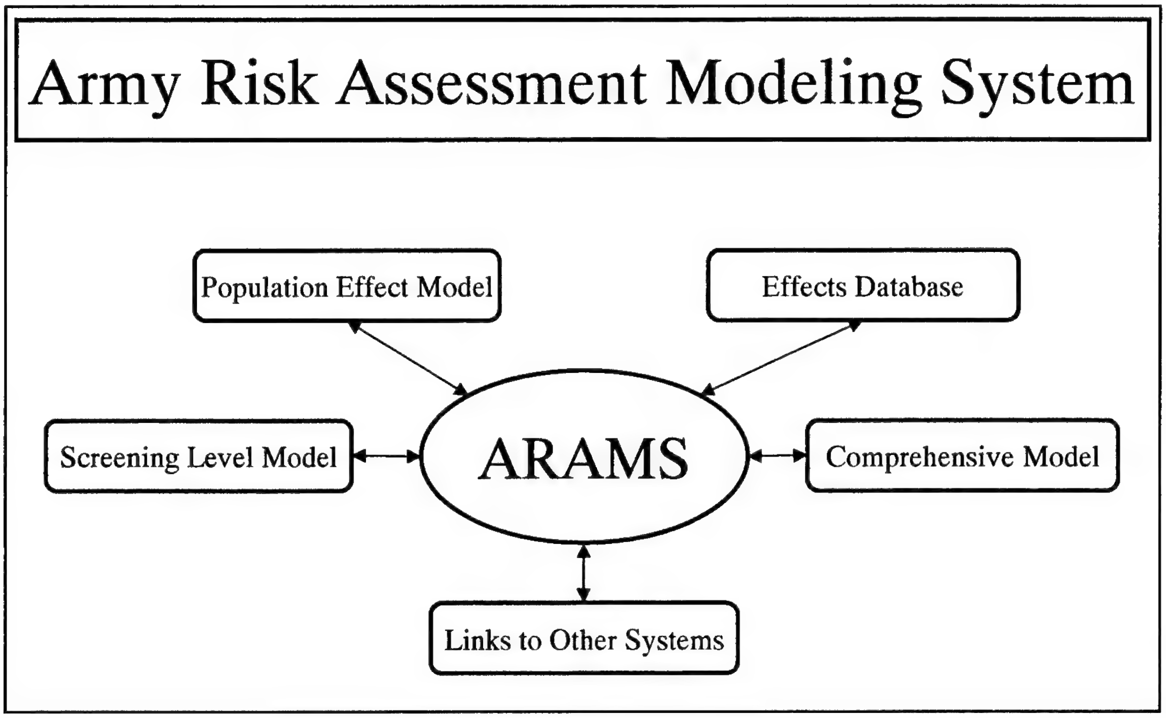

Figure 1. Schematic for the ARAMS

(e) bioaccumulation databases, and (f) effects databases (Figure 1). The uncertainty element will be built into each component of ARAMS. This feature permits users to quantify uncertainty and conduct sensitivity analysis at any point during a simulation. An additional feature of the system is that it will be linked to several systems and legacy codes.

Screening-level model

The screening-level component contained within ARAMS can be used for conducting simple or screening-level risk assessments. Simple risk assessment refers to exposure concentrations estimated from field data while screening level implies that the exposure concentrations are estimated from simple exposure models. Components of the screening-level module include a physico-chemical database, risk calculator, effects database, screening-level exposure models, and linkages to other fate and transport exposure models (Figure 2). To accomplish this objective, the workshop participants recommended the incorporation of FRAMES as the platform for the screening-level model (Whelan et al. 1999).

FRAMES was developed by Pacific Northwest National Laboratory for the DoE. FRAMES is an object-oriented model that is still under development. Within FRAMES will reside a collection of computer algorithms that will simulate the following elements of a transport, exposure, and risk assessment system: contaminant source and release to environment (including surface hydrology), overland flow transport, vadose-zone transport, food-supply

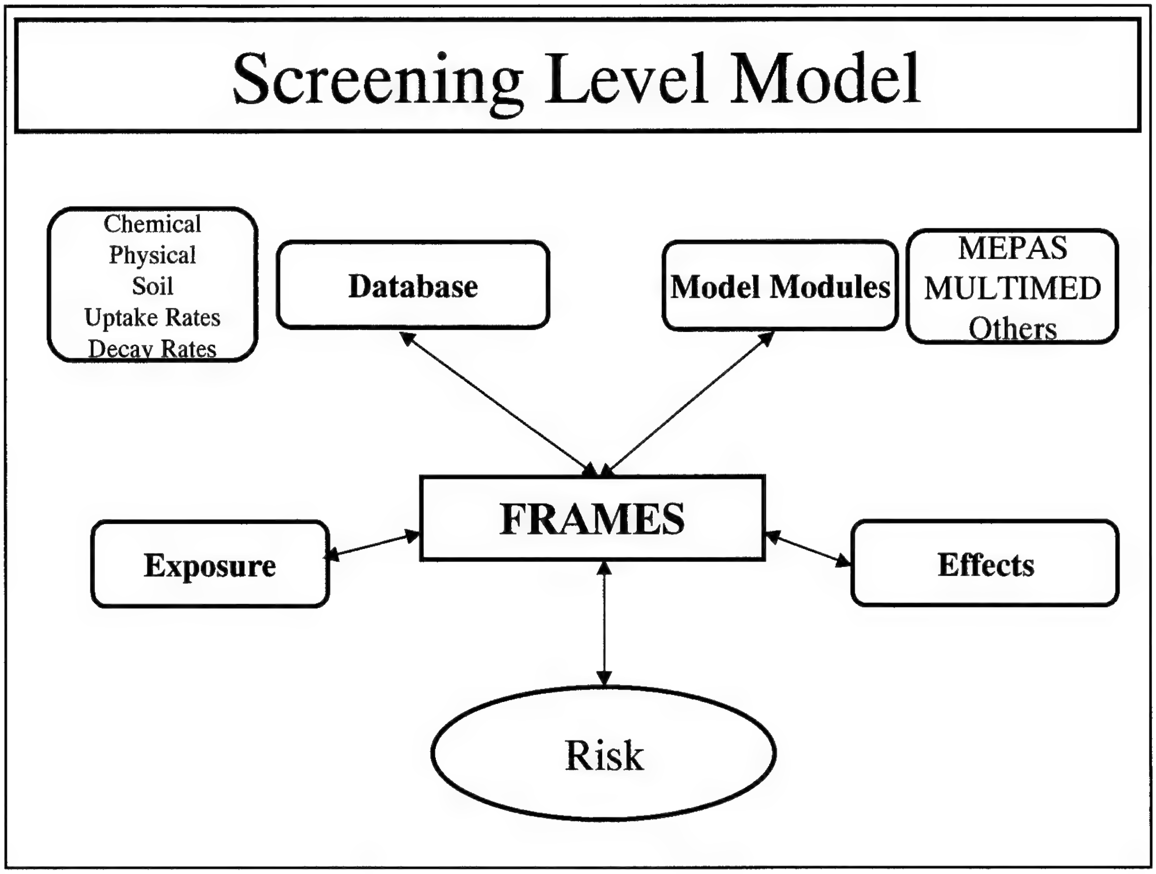

Figure 2. Screening-level model

transport (including animals and plants to humans), intake computation, and health impacts.

The database contained within the screening-level model provides chemical and physical properties, uptake and decay rates, as well as a soil properties characterization tool for input into the exposure modules. The exposure models currently contained within FRAMES are those developed for the Multimedia Environmental Pollutant Assessment System (MEPAS) and Multimedia Exposure Assessment Model (MULTIMED) (Buck et al. 1995, Salhotra et al. 1993).

The human health exposure components include the exposure pathways, the intake routes, and the human health effects database (IRIS and HEAT (Whelan et al. 1999)) containing noncarcinogenic and carcinogenic chemicals as well as radionuclides.

Models that will be included into FRAMES in the near future are RECOVERY and the Hydrologic Evaluation of Landfill Performance (HELP). RECOVERY is a sediment water interaction model to assess the impact of toxicants in the aquatic environment (Boyer et al. 1994). HELP is a landfill modeling tool to assess the movement of contaminants through contaminated

soils and dredge material (Schroeder et al. 1994). It can be applied to evaluate landfill performance.

Comprehensive model

Similar to the screening-level model, the comprehensive model will have access to databases for physcio-chemical properties. The primary difference is that the comprehensive model (CE-QUAL-ICM/TOXI) (Wang et al. in preparation) can account for spatial and temporal variance in exposure estimation (Figure 3). Processes within the comprehensive model include chemical and solids transport in the water column and sediment bed, sorption to dissolved organic matter and three solids (sand, silt, and clay), chemical and biological degradation, and volatilization (Wang et al. in preparation). In addition, modules for addressing trophic transfer, bioaccumulation, and bioconcentration of contaminants will be available.

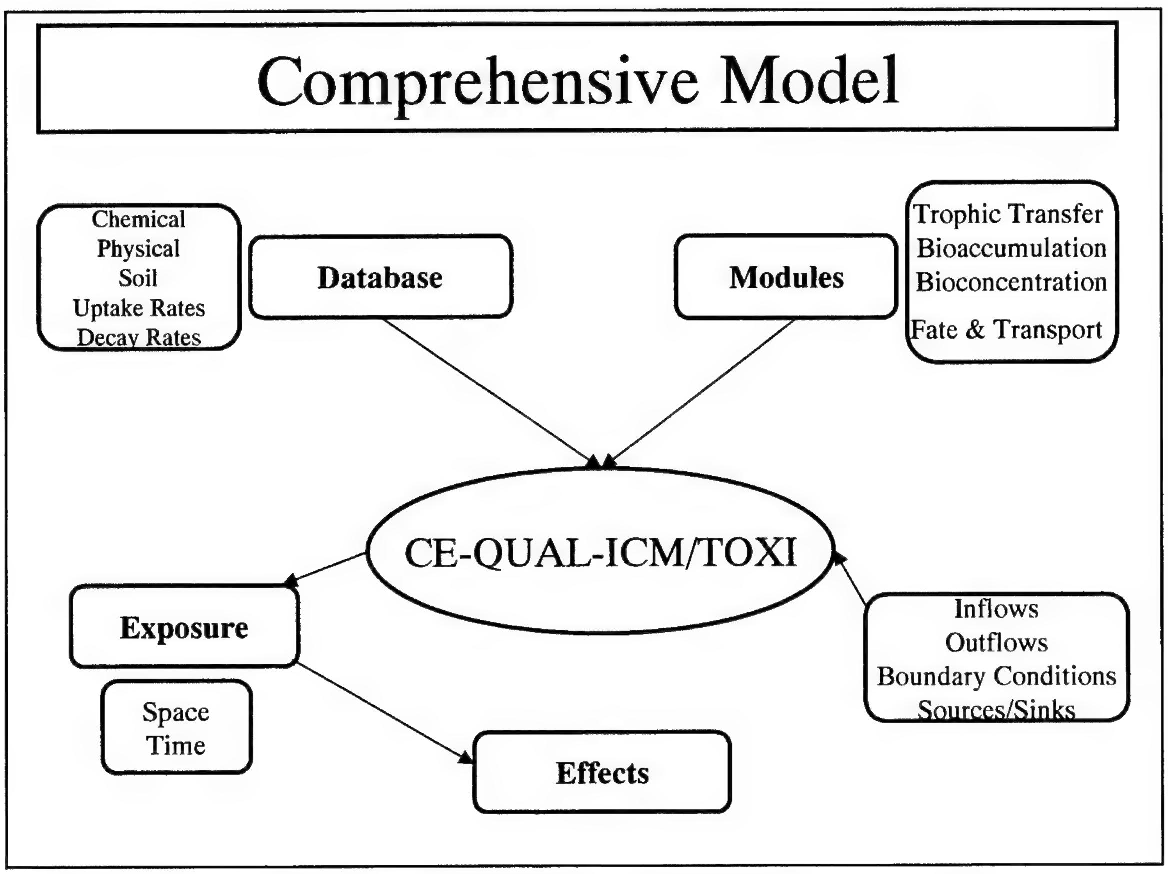

Figure 3. Comprehensive model

CE-QUAL-ICM/TOXI (Wang et al. in preparation) must be linked to comprehensive hydrodynamics codes such as CH3D and RMA10 (Environmental Modeling Research Laboratory 1998b) that compute the input required to run the water quality and contaminant transport model. In addition,

the user has to provide extensive input relating to contaminant boundary conditions, sources and sinks, and contaminant inflows and outflows.

The model produces exposure concentrations in the water column and sediment bed over time and space (one-, two-, or three-dimensional (1-D, 2-D, 3-D)). This information can be exported to other ARAMS modules or can be coupled with the effects database to estimate a comprehensive human or ecological risk assessment.

Population-effect model (PEM)

Population-effect models will be included in ARAMS to estimate the risk to single organisms, populations, and ecosystems. Both aquatic and terrestrial effects components will be incorporated. The first step is the determination of the effect on a single organism. Once this is achieved, the population models can be utilized to estimate the overall effect on a given population. For example, effects that can be seen in the environment can correspond to reduction in fertility, survival of young and adults, and susceptibility to predation. Initially, the metapopulation effect models included in ARAMS will be for an estuarine amphipod and a marine polychaete (Figure 4). The coupling of these and other metapopulation modules will allow for an evaluation of the interactions of population groups and the effect of contaminant exposure within a given population, resulting in an ecological risk assessment.

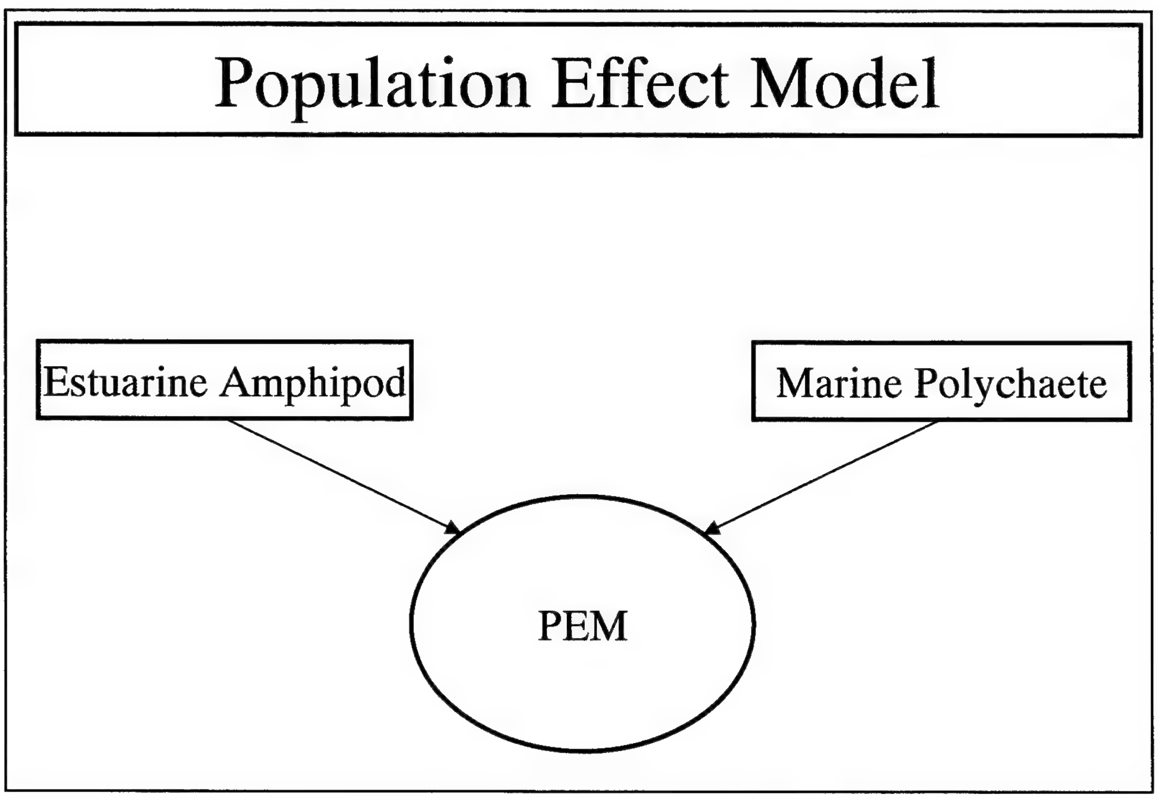

Figure 4. Population-effect model

Another component of the population-effect model will be the incorporation of food chains or food webs. This feature will allow for the evaluation of trophic transfers of contaminants in the ecosystem. Coupling these population effects models with the exposure data predicted from the comprehensive models will provide a comprehensive environmental risk assessment.

Effects database

An integral part of any risk assessment modeling system is the effects database. The effects database provides the relationship between the exposure concentration and the effects to individual organisms. The effects database in ARAMS will contain the Environmental Residue-Effects Database (ERED) and the Biota-Sediment Factor Database (BASF) (Figure 5). ERED is a compilation of literature data where both biological effects and tissue contaminant concentration were simultaneously measured in the same organism. Biological effects refer to a measured or observed effect such as reduced survival, growth, reproduction, etc. Currently, the biological effects within an organism are limited to those linked to specific contaminants observed in the tissue.

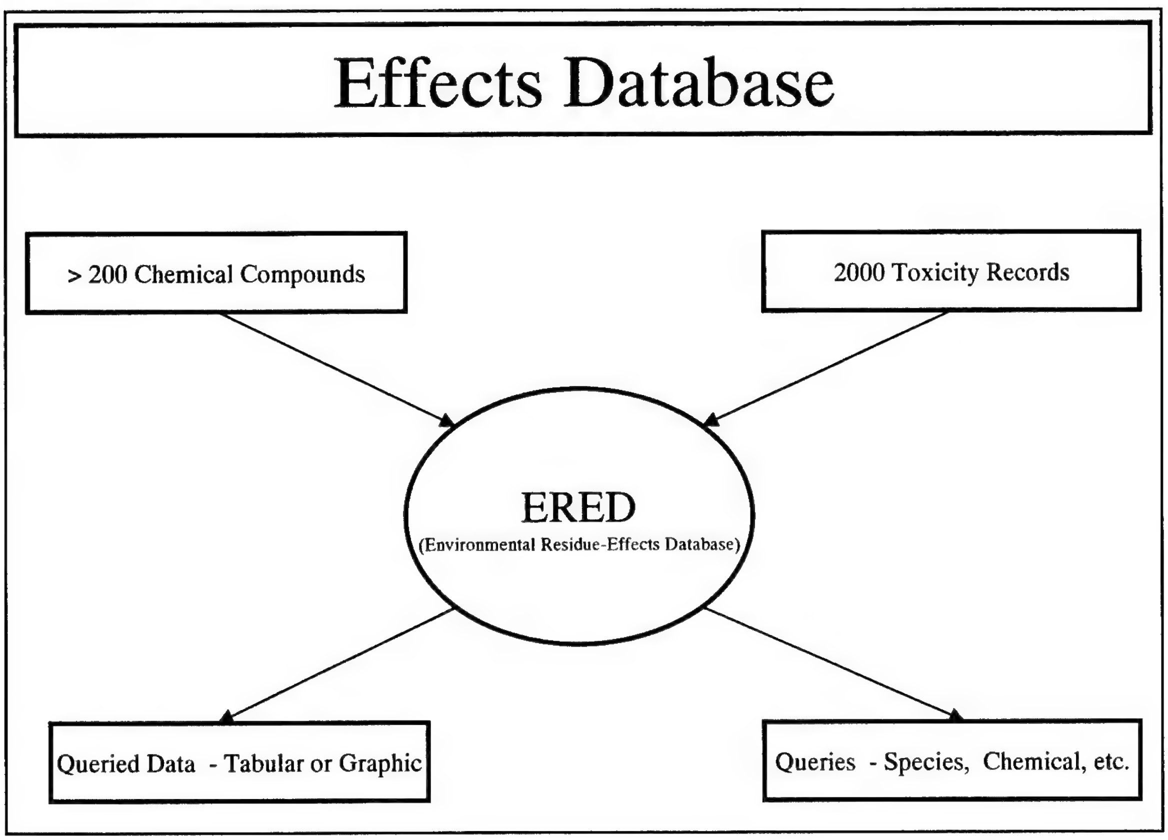

Figure 5. Effects database

The ERED database contains some organism bioaccumulation data, although bioaccumulation is a measurable phenomena rather than an effect. The measured or predicted level due to bioaccumulation is not sufficient information to conclude that the contaminant will produce an adverse effect. The key is to compare the level due to bioaccumulation to a measurable biological effect like those in the ERED database.

The BASF database is a collection of laboratory and field generated BASF numbers. The database also contains lipid values for numerous organisms which can be used in lieu of actual organism lipid content. BASF numbers are used to predict more environmentally realistic bioaccumulation levels when using the Thermodynamic Bioaccumulation Potential (TBP) formulation. The TBP estimates the bioaccumulation potential directly from the contaminant sediment concentration, organism lipid content, contaminant BASF, and sediment organic carbon.

Links to other systems

Based on workshop consensus, it was decided that the ARAMS would provide links and hooks to access legacy codes and other modeling systems. This component of ARAMS maximizes the use of existing codes with minor development of linkages. Linkages will be developed for transferring input and output between the modules and/or components. Initially, systems that will be linked into the ARAMS will include the three DoD modeling systems which provide a comprehensive graphical user environment (Figure 6). All three DoD modeling systems can be characterized as comprehensive components of ARAMS.

The WMS is used for performing hydrologic and water quality analysis and supports several legacy codes including HEC1, TR-55, CASC2D, and HSPF (Environmental Modeling Research Laboratory 1998a). These models represent both widely used lumped parameter models, as well as more advanced 2-D distributed parameter watershed models. Models contained in the WMS can be used to address the terrestrial component for exposure assessments.

The GMS is used for performing groundwater simulations, site characterizations, model conceptualizations, and geostatistical interpretation (Environmental Modeling Research Laboratory 1999). GMS supports several legacy codes including MODFLOW, FEMWATER, MT3D, RT3D, and SEAM3D. These models represent more advanced 3-D water and contaminant transport models for exposure for human (drinking wells) and ecological exposure (groundwater-surface water interactions). Models contained in the GMS can be used to address the groundwater component for exposure assessments.

The SMS is used for performing model conceptualization, mesh generation, statistical interpretation, and visual examination of surface water model

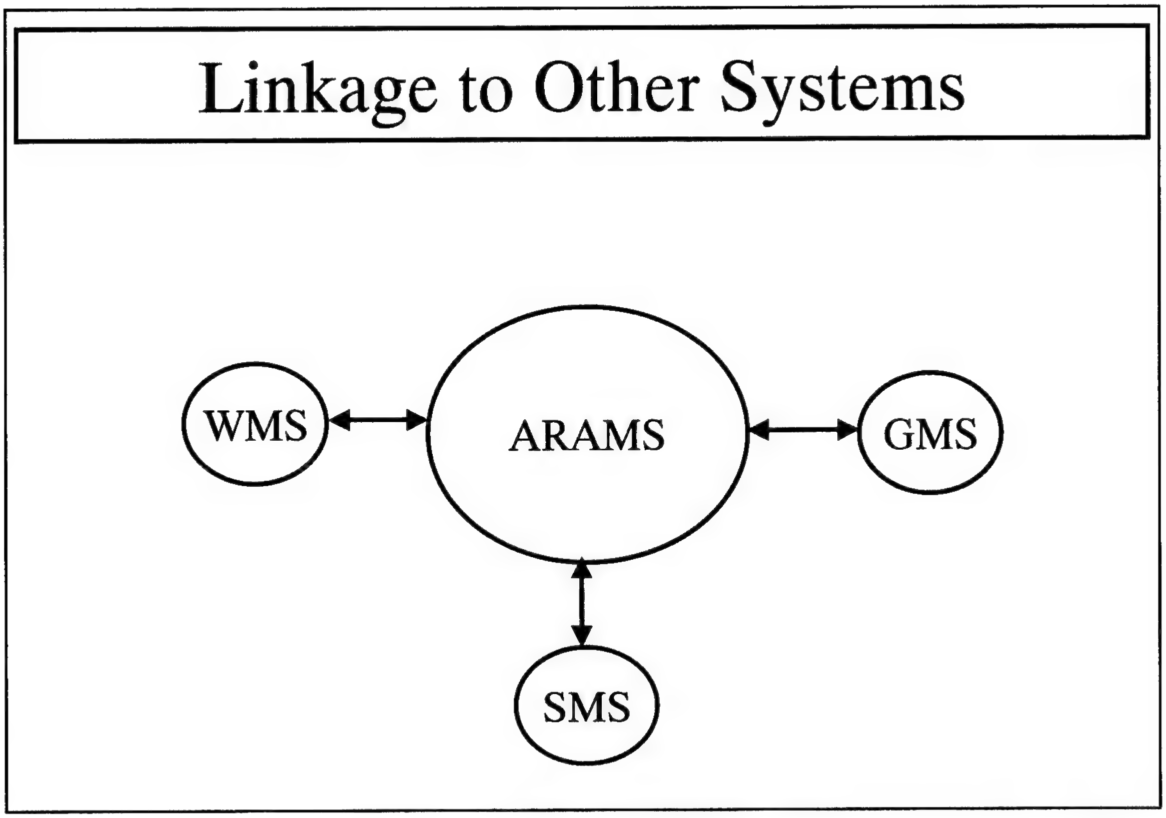

Figure 6. Linkage of ARAMS to existing comprehensive modeling systems

simulations (Environmental Modeling Research Laboratory 1998b). SMS supports several hydrodynamics and water quality legacy codes including RMA10, TABS-MD, CH3D, and CEWES-ICM (Wang et al. in preparation). Models contained in the SMS can be used to address the aquatic component for exposure assessments including both water column and bottom sediments.

Future efforts will include linkage of additional legacy codes from the EPA, USGS, DoE, and universities. The ARAMS flexible design will allow implementation of other systems and legacy codes without the burden of maintenance. This is accomplished through the ARAMS by providing only the linkage to these systems. Code maintenance will be the responsibility of the owners of the legacy codes and modeling systems.

3 Workshop Recommendations

During the workshop a list of system attributes was developed for ARAMS. The list was made in an effort to provide a flexible framework that would allow for adaptation of emerging technologies as well as provide the users seamless access to databases contained at web-site locations. For ARAMS to be successful, the consensus was that the following points would have to be addressed by the system:

- Web-Based, Network Services
- Ecologically Oriented and Spatially Explicit
- Contains Components for Both Human & Ecological Risk
- Standard Hooks Between Models
- Integration of Legacy Models
- Modular to Include New Models, Science
- Couples Exposure, Fate, Effects, Uncertainty, Economics - Risk vs Cost
- Launches Off User's Desktop, Probably in Windows NT, Supports UNIX, PCs
- Transport Use if Used for High Performance Computing (HPC)
- Data Standards to Allow as Seamless as Possible Data Access
- Client/Server Relationships to Access Remote Data, Simulations
- Multimedia from Outset
- Differing Levels of Tools From Screening to HPC

- Leverage Funding from Other Federal Sources
- Self Defensive Software - Units, Range Checking
- Security "Black Box" - For Certain Military Applications
- Smart - Adaptive Software

The development of ARAMS is anticipated to take several years to complete. One last major point discussed at the workshop was the necessity of choosing a proper location to test the system. A site would have to be chosen with a plethora of data such that screening- and comprehensive-level approaches for risk assessment for both ecological and human risk could be validated.

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Appendix A
Conference Agenda and List of Participants

Conference Agenda

Risk Assessment Modeling Workshop
Final Agenda

May 14, 1998

07:30 - 08:30	*Registration*
08:30 - 08:40	*Introduction to the Risk Assessment Modeling Workshop* Patrick N. Deliman - U.S. Army Engineer Waterways Experiment Station
08:40 - 08:50	*Fate & Effects Modeling Concepts* Richard E. Price - U.S. Army Engineer Waterways Experiment Station
08:50 - 09:00	*Ecological Risk Assessment Concepts* Todd Bridges - U.S. Army Engineer Waterways Experiment Station
09:00 - 09:45	*Deployment Exposure Surveillance System* Jack Heller and William Legg - U.S. Army Center for Health Promotion & Preventive Medicine
09:45 - 10:15	*WEB Based Approach for Developing Risk Assessment Modeling System* Jeffery Holland - U.S. Army Engineer Waterways Experiment Station

10:15 - 10:30	BREAK
10:30 - 11:00	*Groundwater Modeling System (GMS)* Jeffery Holland - U.S. Army Engineer Waterways Experiment Station
11:00 - 11:30	*The Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)* Gene Whelan - Battelle Pacific Northwest National Laboratory
11:30 - 12:00	*Dredged Material Modeling - Risk Based Concepts* Paul Schroeder - U.S. Army Engineer Waterways Experiment Station
12:00 - 13:30	LUNCH
13:30 - 14:00	*Bioaccumulation Modeling Concepts and Principles/Contemporary Issues* Bob Thomann - Manhattan College
14:00 - 14:30	*Ecosystem Models for Ecological Risk Analysis: From Single Species to Communities* Scott Ferson - Applied Biomathematics
14:30 - 15:00	*You Don't Need to Know A Lot of Ecology to Make a Comprehensive Ecological Risk Assessment* Scott Ferson - Applied Biomathematics
15:00 - 15:30	BREAK
15:30 - 16:00	*Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model* Bill Mills - TETRA TECH, INC.
16:00 - 16:30	*Metapopulation Models and Ecological Risk Analysis: A Habitat-based Approach to Biodiversity* H. Resit Akcakaya - Applied Biomathematics
16:30 - 17:00	*Ecological Risk in an Integrated Intermedia System* Gene Whelan - Battelle Pacific Northwest National Laboratory
17:00 - 17:30	*Exposure Assessment - Trophic Transfer to Birds* David Glaser - Quantitative Environmental Analysis
18:30 - 20:00	COMPUTER SOFTWARE DEMONSTRATIONS

May 15, 1998

08:00 - 10:00	*Discussion of Risk Assessment Modeling Concepts for Military Needs* Carlos E. Ruiz - U.S. Army Engineer Waterways Experiment Station
10:00 - 10:30	BREAK
10:30 - 12:00	*Discussion Continued*
12:00 - 13:30	LUNCH
13:30 - 15:00	*Workshop Summary & Conclusions*
15:00 - 15:30	*Adjourn*

List of Participants

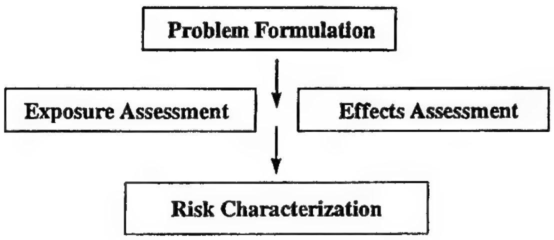
Risk Assessment Modeling Workshop
May 14-15th 1998

Name:	Affiliation:
H. Resit Akcakaya	Applied Biomathematics
Dennis L. Brandon	U.S. Army Corps of Engineers - WES
Jim Brannon	U.S. Army Corps of Engineers - WES
Todd Bridges	U.S. Army Corps of Engineers - WES
Patrick N. Deliman	U.S. Army Corps of Engineers - WES
Val Emery	U.S. Army Corps of Engineers - WES
Scott Ferson	Applied Biomathematics
Jeff Gerald	AscI, Inc.
David Glaser	Quantitative Environmental Analysis, LLC.
Jeff Holland	U.S. Army Corps of Engineers - WES
Mark S. Johnson	U.S. Army Center for Health Promotion & Preventive - CHPPM
Glenn Leach	U.S. Army Center for Health Promotion & Preventive - CHPPM
William E. Legg	U.S. Army Center for Health Promotion & Preventive - CHPPM
Bill Mills	Tetra Tech. Inc.
Richard E. Price	U.S. Army Corps of Engineers - WES
Carlos E. Ruiz	U.S. Army Corps of Engineers - WES
Toni Schneider	U.S. Army Corps of Engineers - WES
Paul Schroeder	U.S. Army Corps of Engineers - WES
Larry Tannenbaum	U.S. Army Center for Health Promotion & Preventive - CHPPM
Robert V. Thomann	Manhattan College
Gene Whelan	Pacific Northwest National Laboratory

Appendix B
Ecological Risk Assessment Concepts

This appendix contains the presentation documents for "Ecological Risk Assessment Concepts" by Todd Bridges - U.S. Army Engineer Waterways Experiment Station.

Ecological Risk Assessment



DoD and Risk Assessment

- Historical emphasis on human health protection
- Ecological concerns are becoming more prominent

DoD and Risk Assessment

- ERA survey of 190 Army facilities
  - >50% were/anticipated conducting ERA
  - Average estimated ERA cost $1,000K
  - Average per projected eco-based cleanup costs, $500K-$6,000K
  - Ecological concerns resulted in programmatic delays of 3 mos to 2 yrs

DoD Risk Assessment Needs

- Modeling/software tools for risk characterization
  - Currently, detailed exposure information is ineffectively combined with effects information
    - Effects information poorly organized
    - Hazard quotients are inefficient

DoD Risk Assessment Needs

- Modeling/software tools for projecting effects beyond individual organisms
  - Human health model generally inappropriate for assessing ecological risk
  - Concern should be focused on higher order effects
    - "Toxic substances have effects at the level of cellular biochemistry, but their ecological consequences are at the levels of the population, community, and ecosystem. Thus, there is a translation problem at the core of ecotoxicology: how to translate mechanisms at one level into effects at another." Caswell, 1996

DoD Risk Assessment Needs

Modeling/software tools for incorporating spatial and temporal issues when assessing risk

- Space is a primary resource and key determinate of exposure
  - "The absence of space as a dimension in ecotoxicological risk assessment seems puzzling upon reflection... Spatially explicit risk assessment is limited largely by the available effects models. The organism, population, and ecosystem effects models currently in use nearly always assume homogeneous exposure and responses." Suter, 1993.
- The risk today is not the risk tomorrow

DoD Risk Assessment Needs

- Modeling/software tools for quantifying uncertainties
  - Variation dominates ecological systems
  - Risk is the probability of an adverse event
  - "If a man will begin with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties." Francis Bacon, 1561-1626

Appendix C
Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)

This appendix contains the presentation documents for "The Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)" by Gene Whelan - Battelle Pacific Northwest National Laboratory.

Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)

Gene Whelan, Ph.D

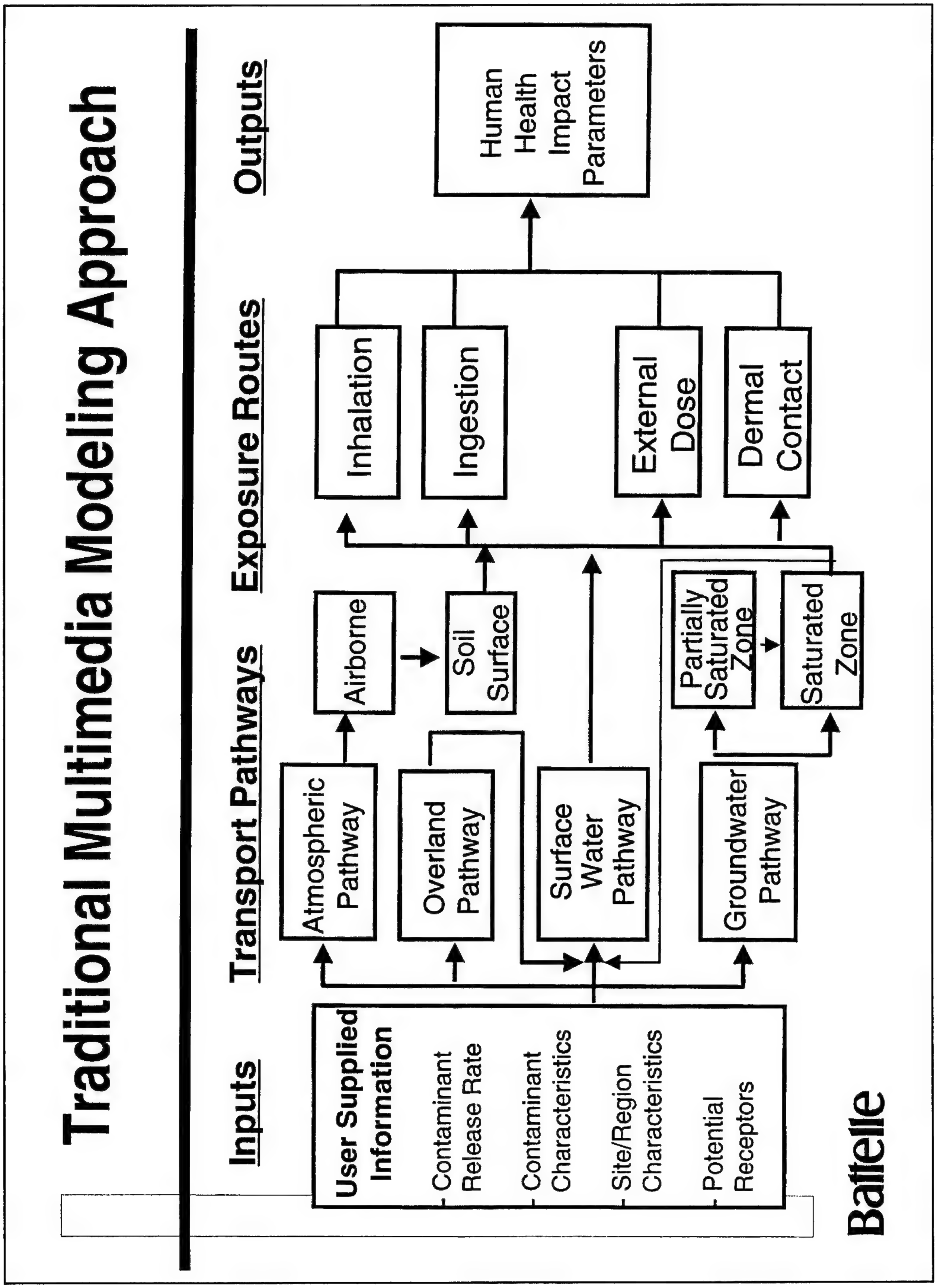
Pacific Northwest National Laboratory
Richland, Washington

Battelle

FRAMES

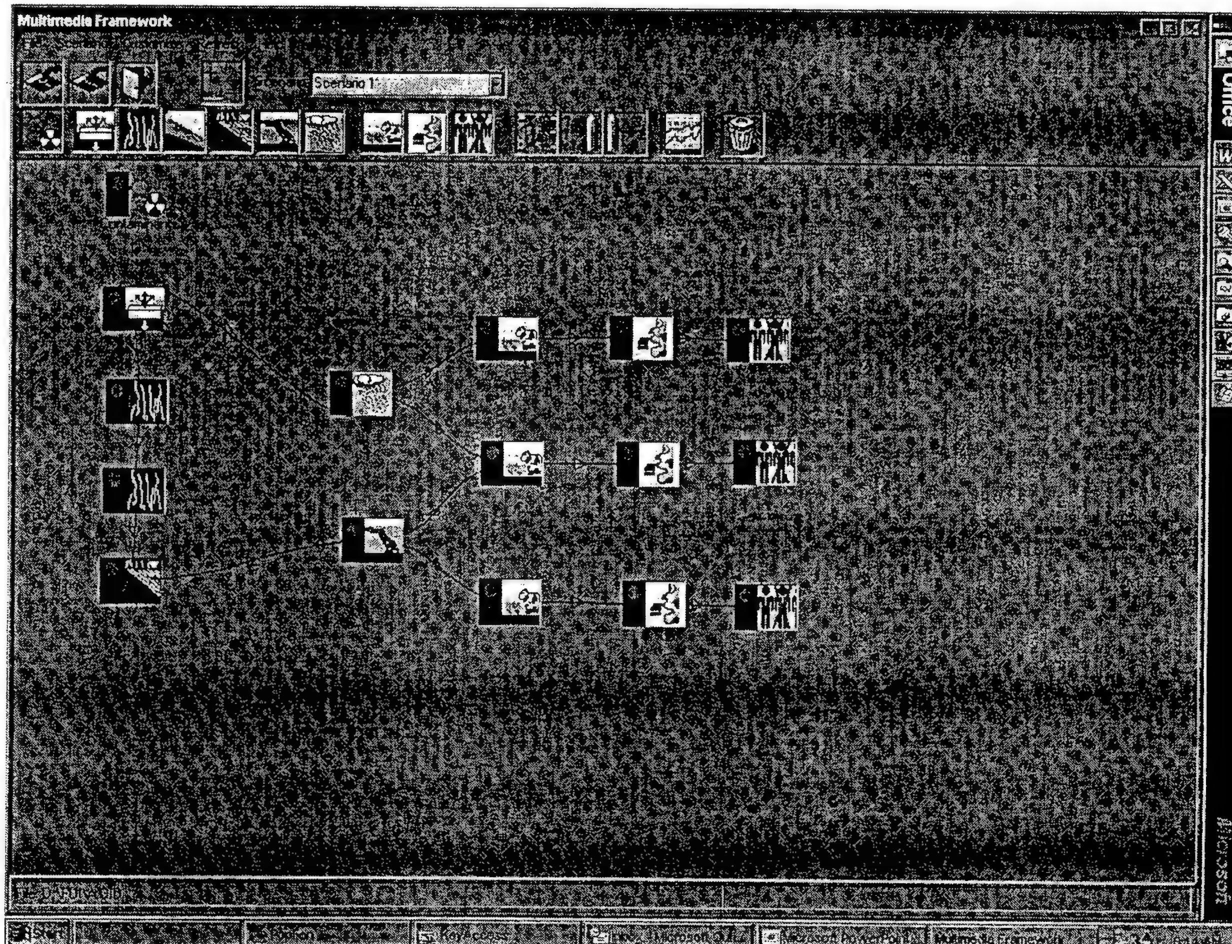
- FRAMES is a software platform that allows models, developed by different people, to link and communicate with each other, while maintaining the legacy of the originals models.

Battelle



Traditional Multimedia Modeling Approach
Inputs
Transport Pathways
Exposure Routes
Outputs
User Supplied Information
Contaminant Release Rate
Contaminant Characteristics
Site/Region Characteristics
Potential Receptors
Atmospheric Pathway
Overland Pathway
Surface Water Pathway
Groundwater Pathway
Airborne
Soil Surface
Partially Saturated Zone
Saturated Zone
Inhalation
Ingestion
External Dose
Dermal Contact
Human Health Impact Parameters
Battelle

Non-Traditional Multimedia Modeling Approach



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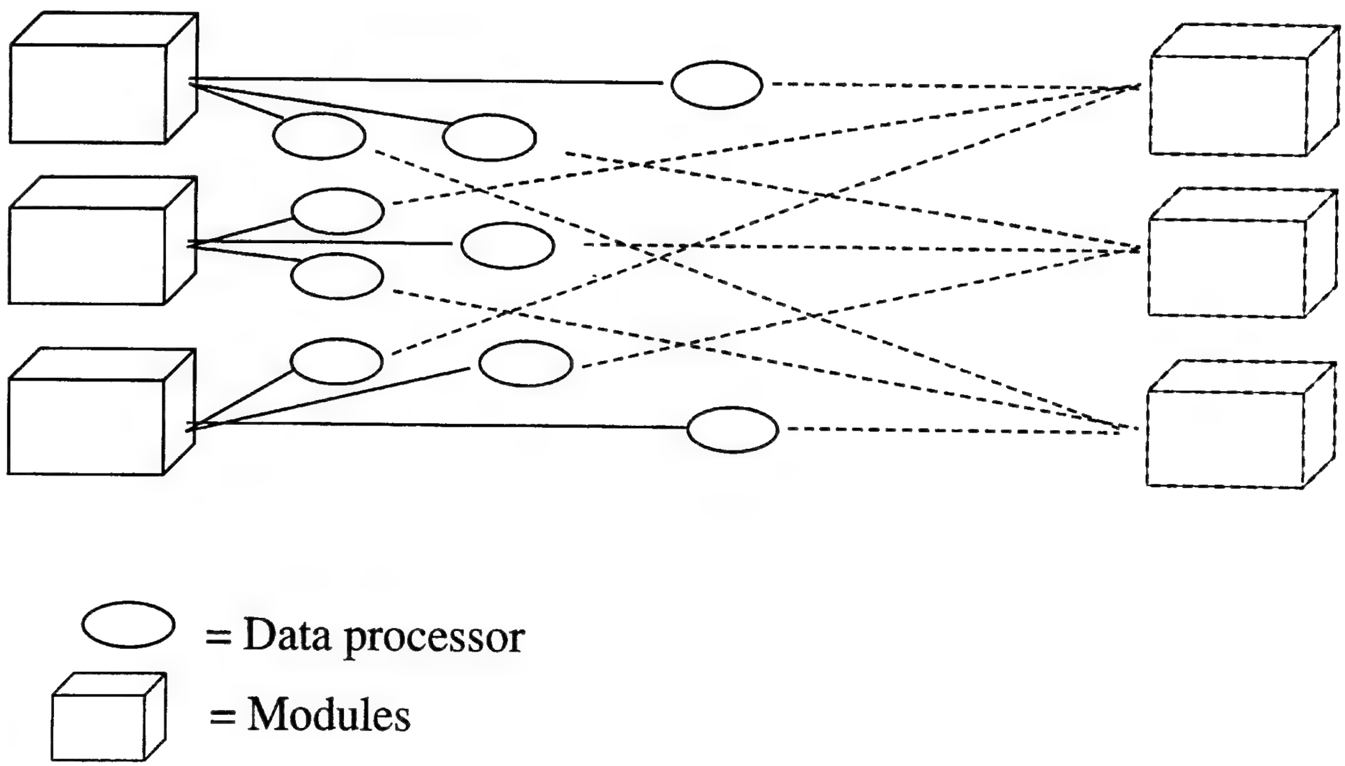
Traditional Approach to Linking Models



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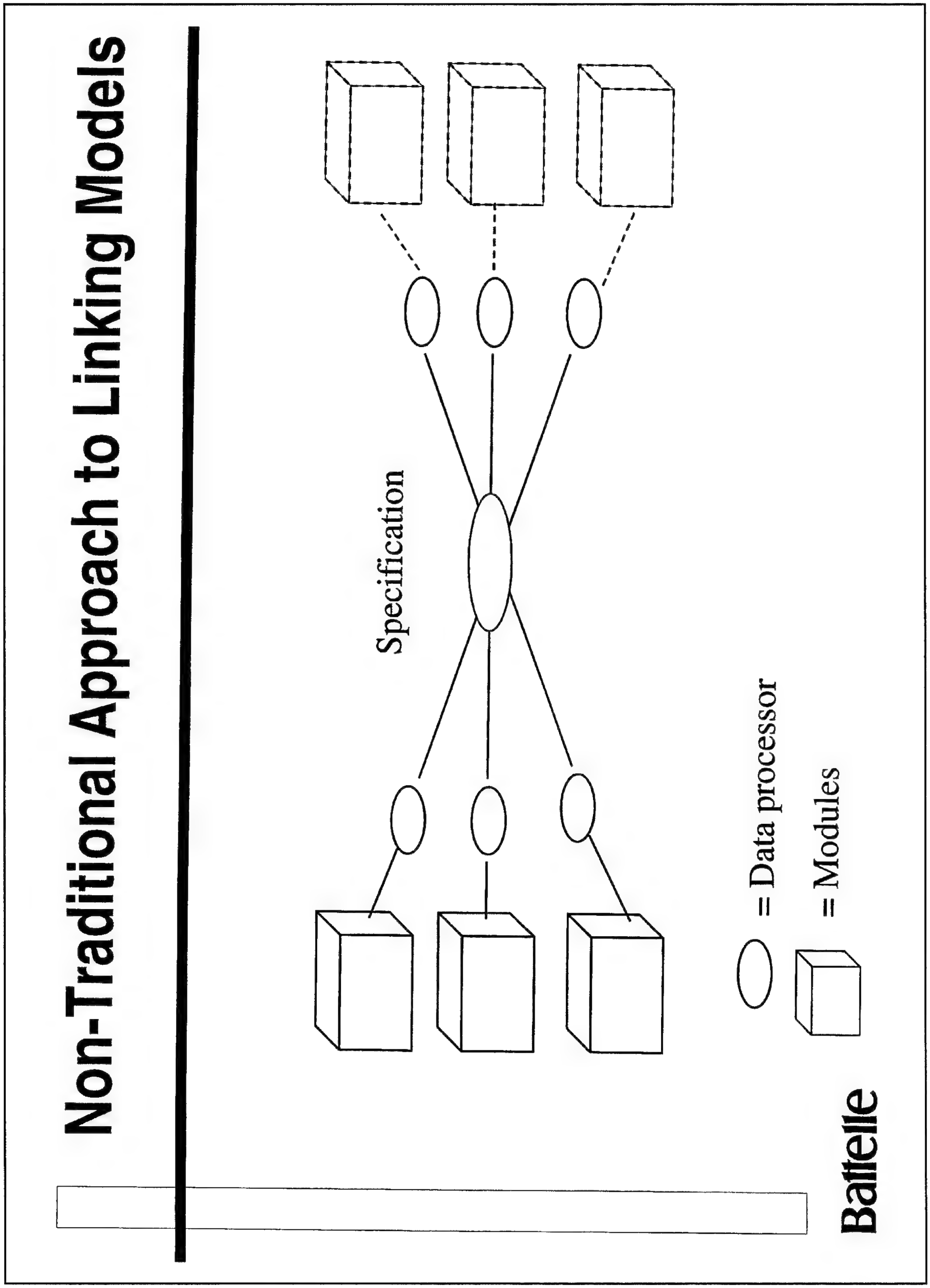
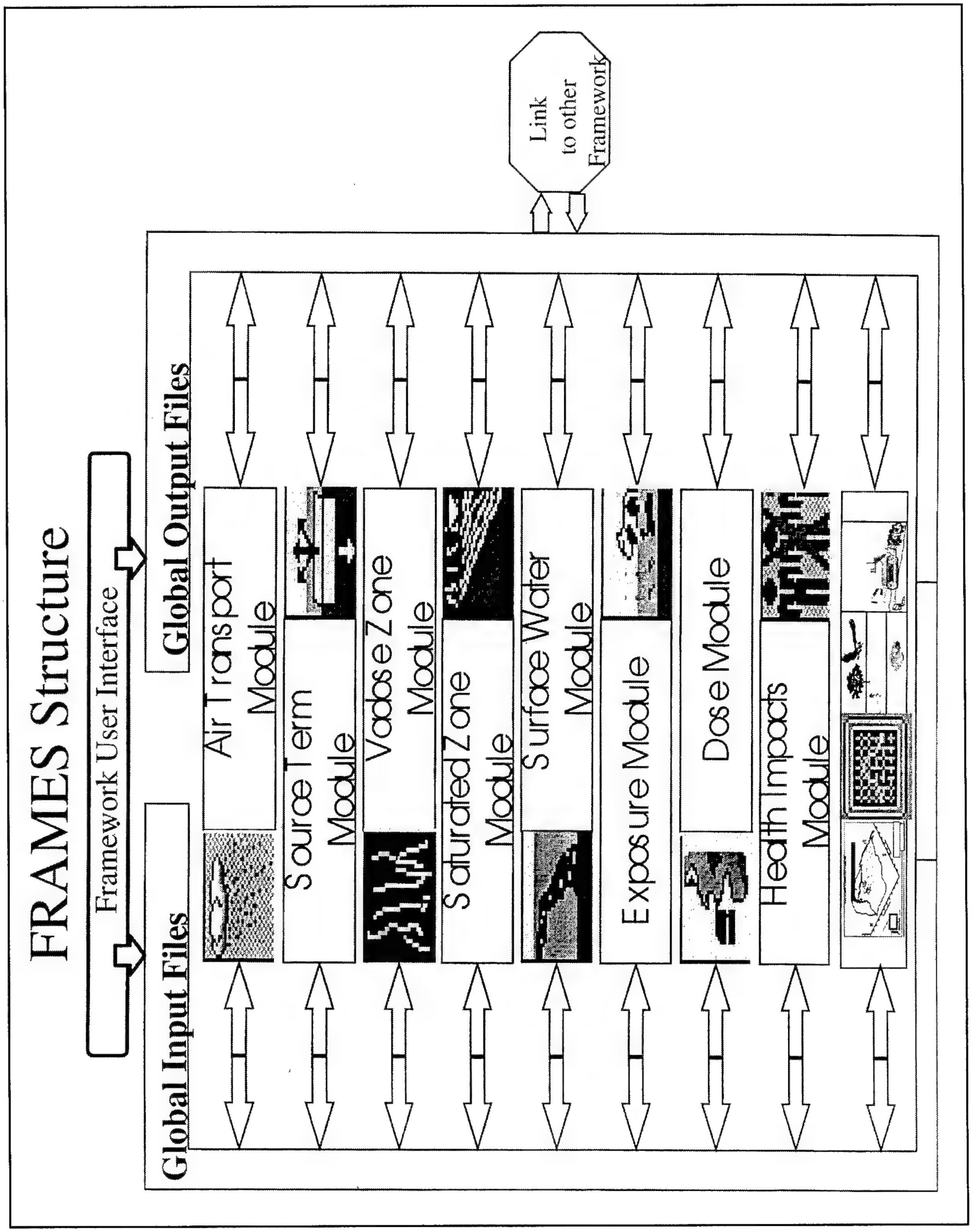
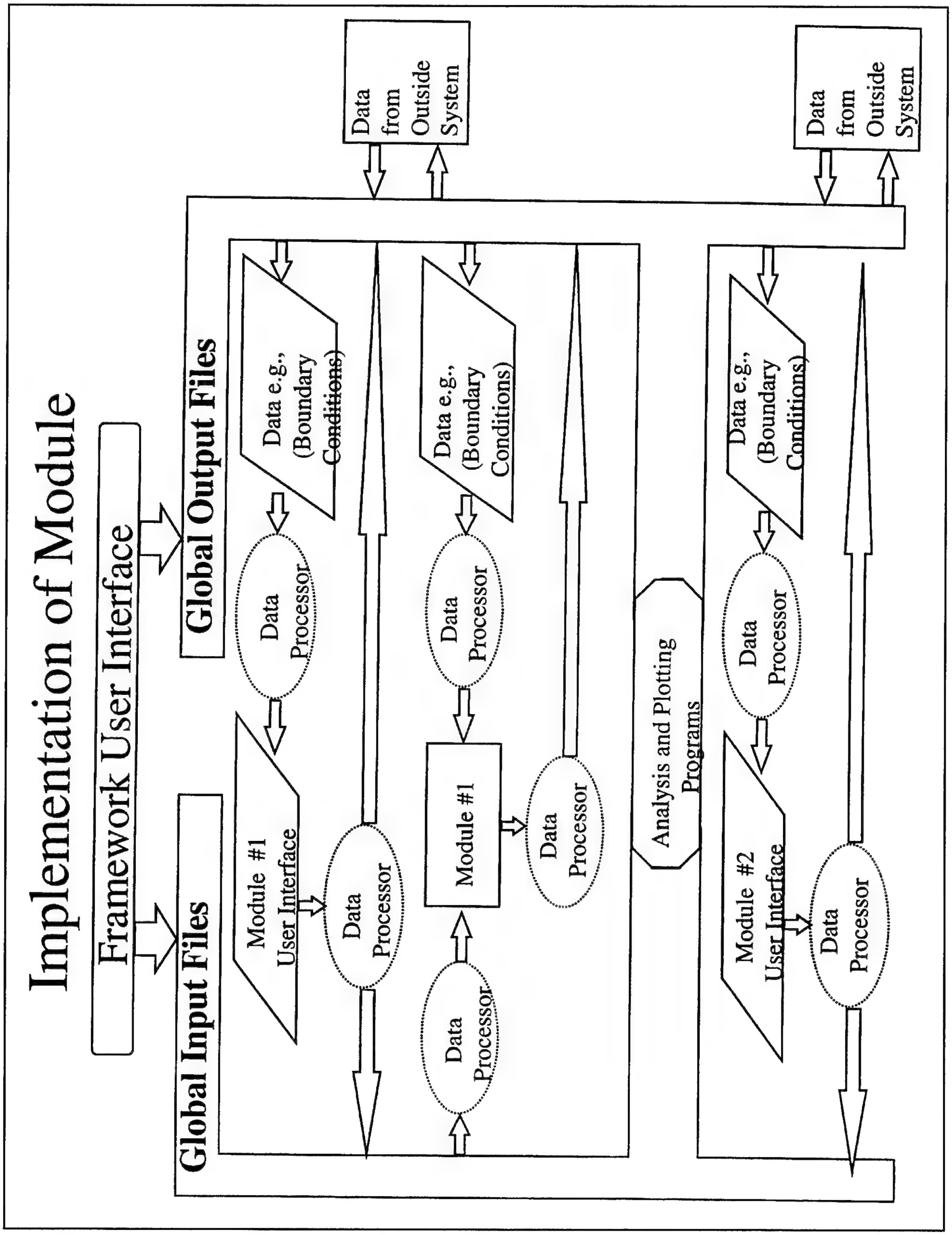

Non-Traditional Approach to Linking Models
Specification
= Data processor
= Modules
Battelle

Purpose of Framework

- View all models as common objects
- Provide common data specifications for suite of objects
- Require minimal modifications to models
- Link to other framework environments

Battelle


FRAMES Structure
Framework User Interface
Global Input Files
Global Output Files
Air Transport Module
Source Term Module
Vadose Zone Module
Saturated Zone Module
Surface Water Module
Exposure Module
Dose Module
Health Impacts Module
Link to other Framework


Implementation of Module
Framework User Interface
Global Input Files
Global Output Files
Module #1 User Interface
Data Processor
Data e.g., (Boundary Conditions)
Data Processor
Data Processor
Module #1
Data Processor
Data e.g., (Boundary Conditions)
Data Processor
Data from Outside System
Analysis and Plotting Programs
Module #2 User Interface
Data Processor
Data Processor
Data e.g., (Boundary Conditions)
Data from Outside System

Matrix Correlating Mesh Resolution with Scaling Dependency

		SCALE			
		MEDIUM SPECIFIC	WATERSHED	REGIONAL	GLOBAL
RESOLUTION	LOW				
	MEDIUM				
	HIGH				

Battelle

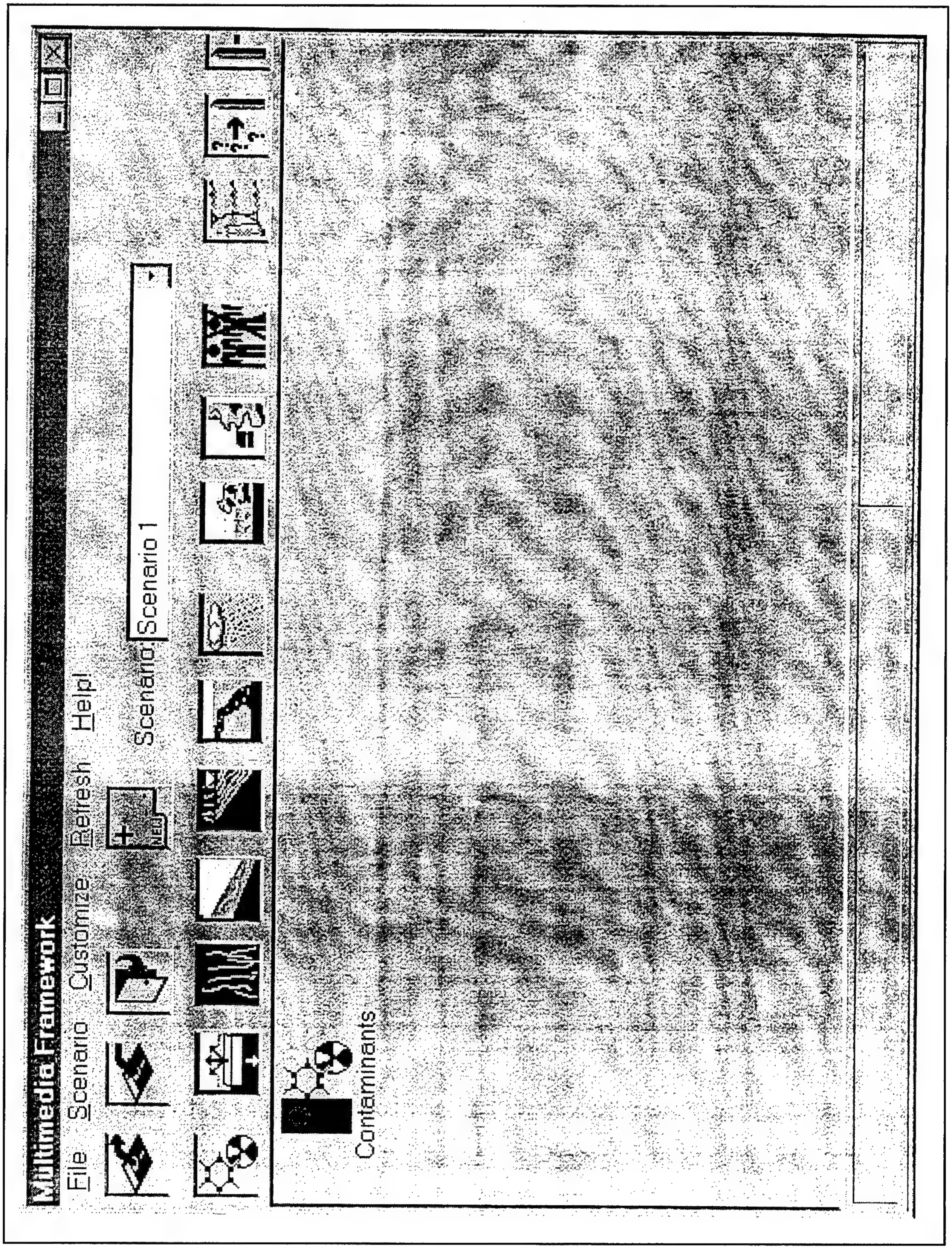
Matrix Correlating Mesh Resolution with Scaling Dependency

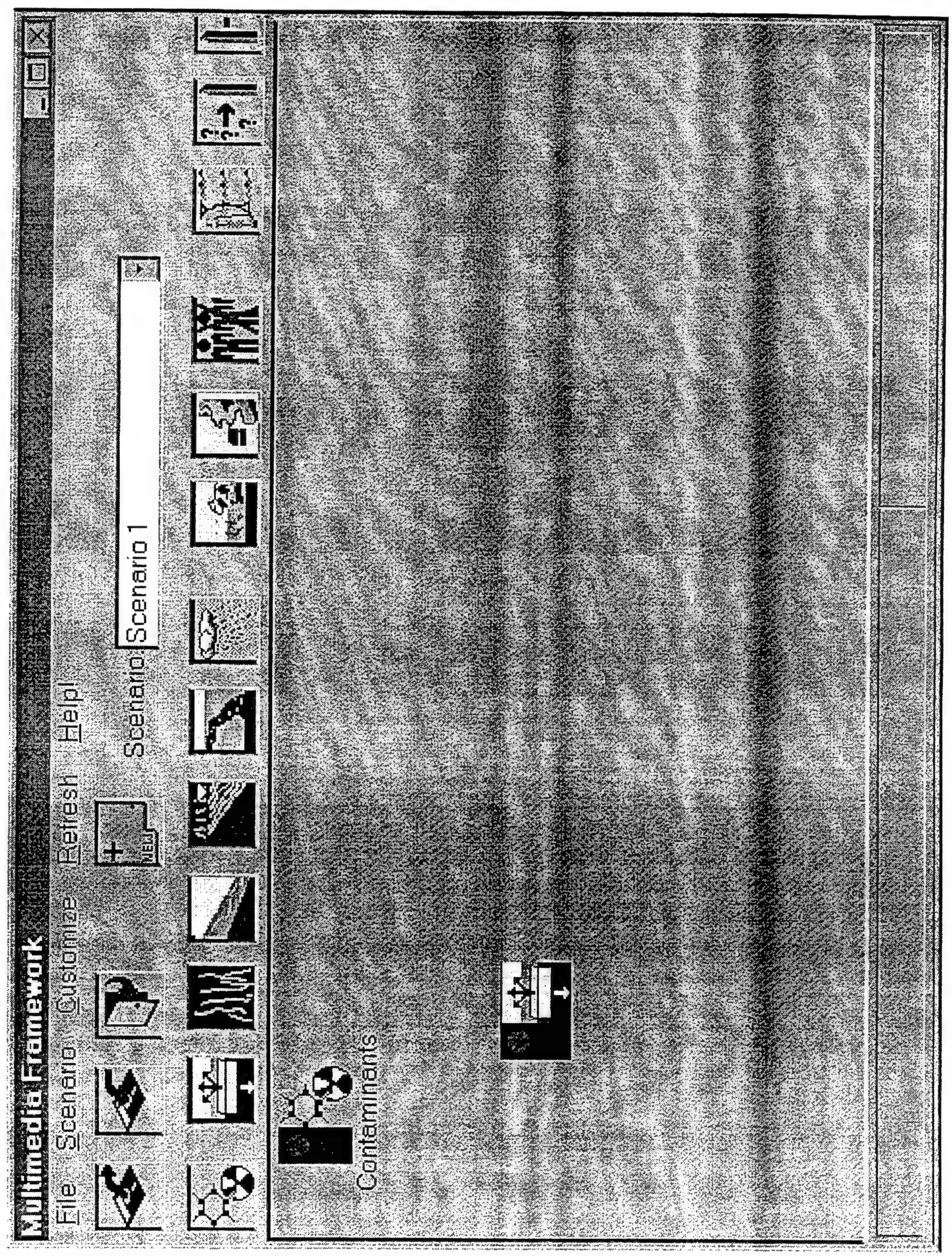
		SCALE			
		MEDIUM SPECIFIC	WATERSHED	REGIONAL	GLOBAL
RESOLUTION	LOW				
	MEDIUM				
	HIGH				

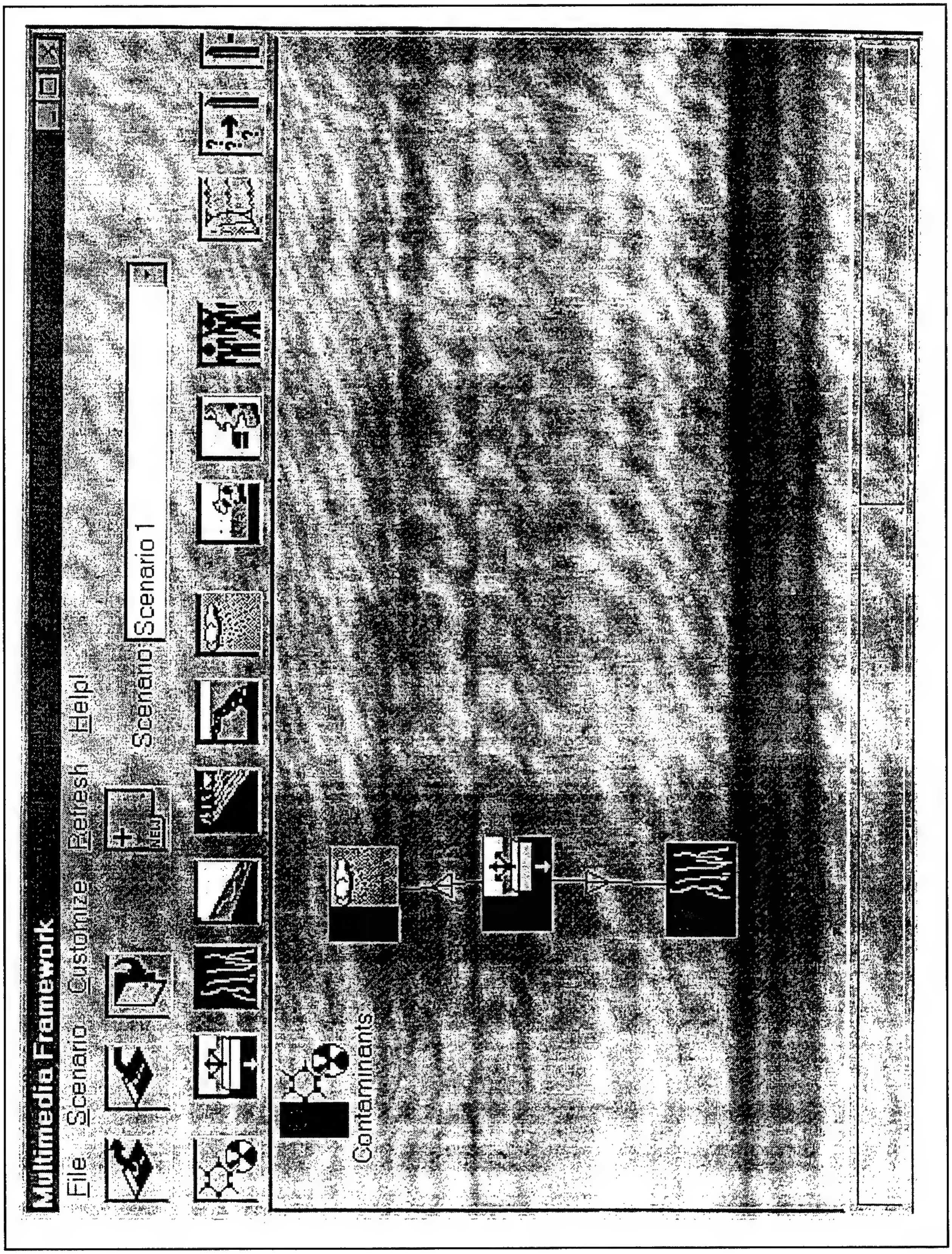
Battelle

Example

Battelle


Multimedia Framework
File Scenario Customize Refresh Help
Scenario: Scenario 1
Contaminants


Multimedia Framework
File
Scenario
Customize
Refresh
Help!
Scenario
Scenario 1
Contaminants


Multimedia Framework
File Scenario Customize Refresh Help!
Scenario: Scenario 1
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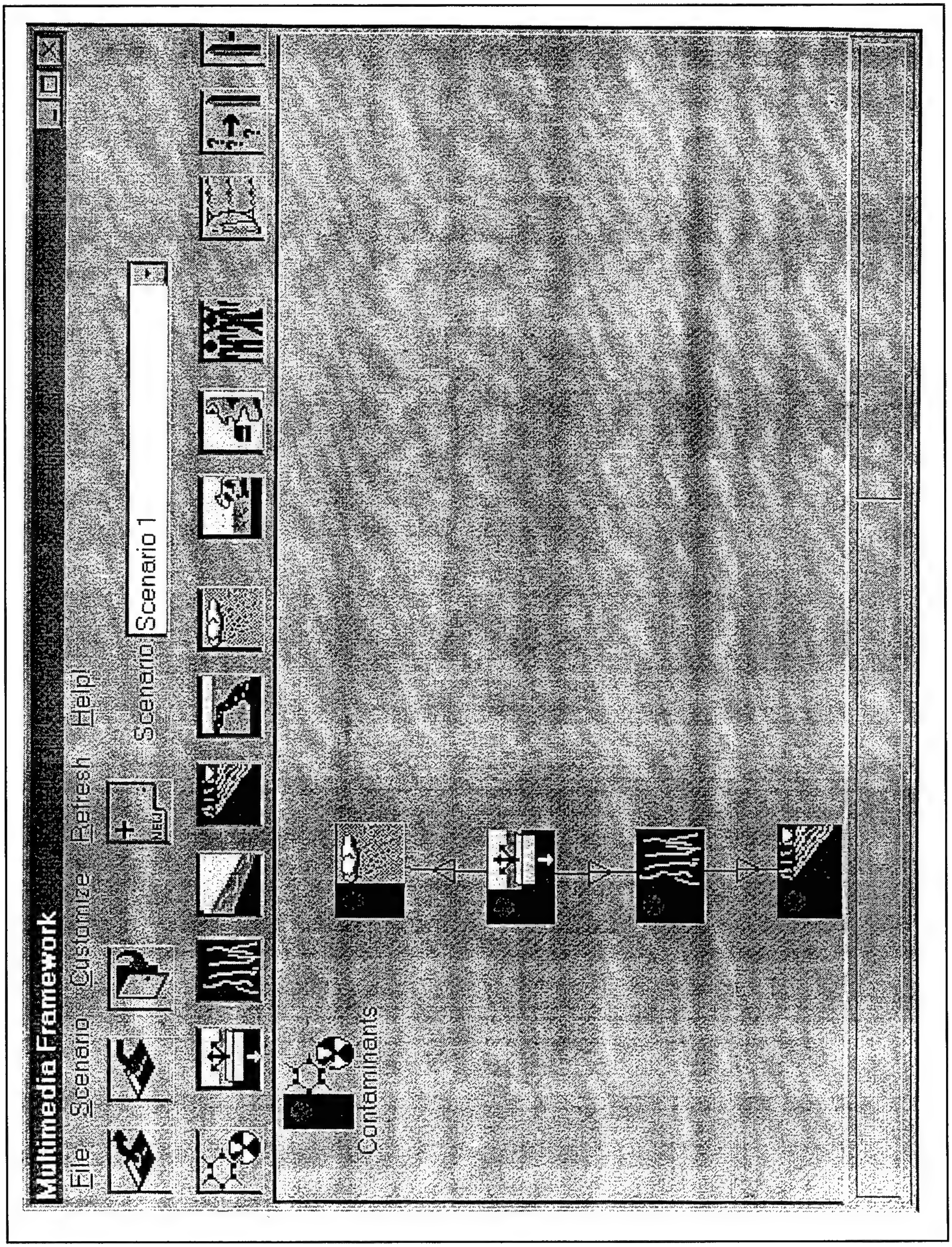
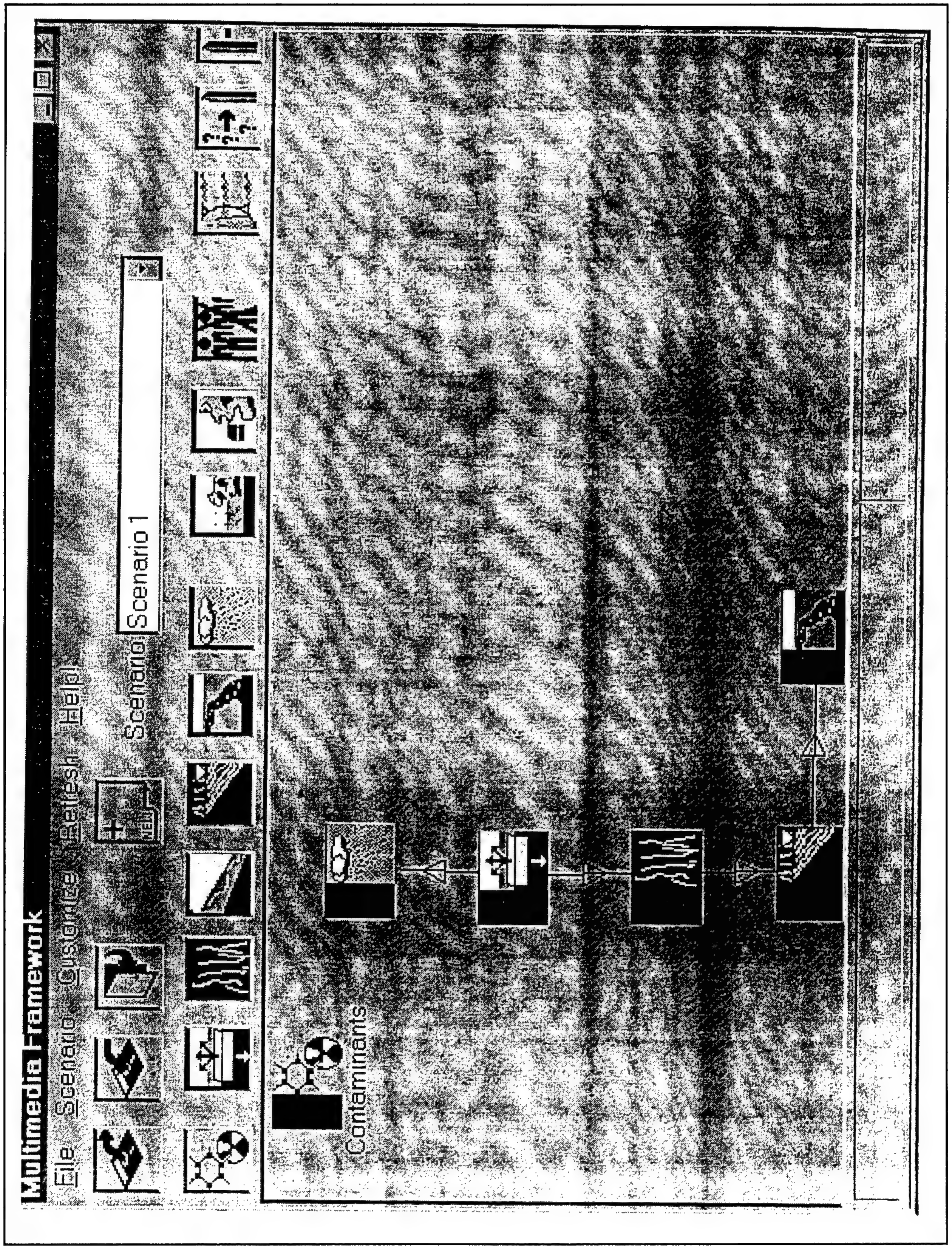
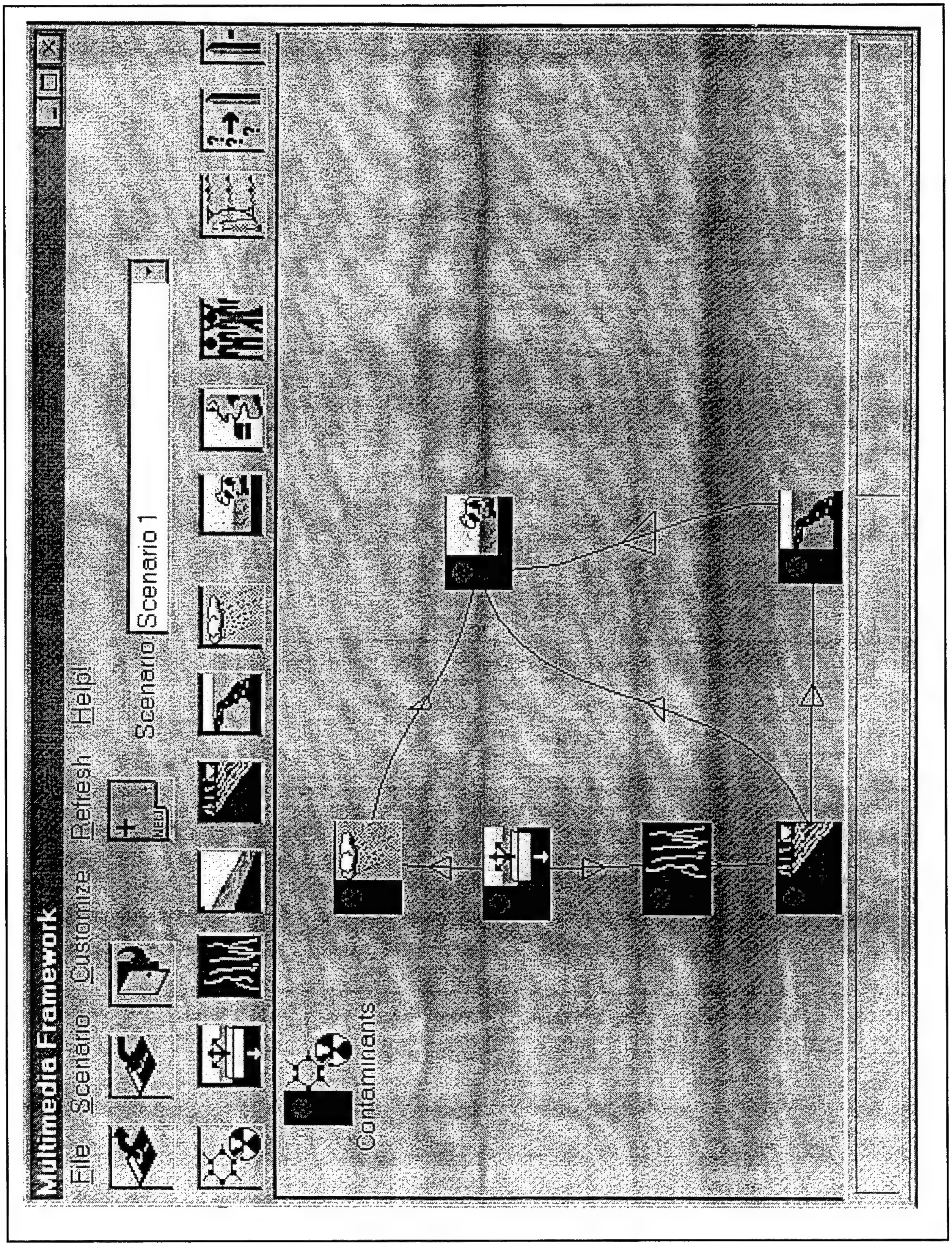

Multimedia Framework
File Scenario Customize Refresh Help
Scenario
Scenario 1
Contaminants


Multimedia Framework
File Scenario Customize Refresh Help
Scenario
Scenario 1
Contaminants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Scenario: Scenario 1
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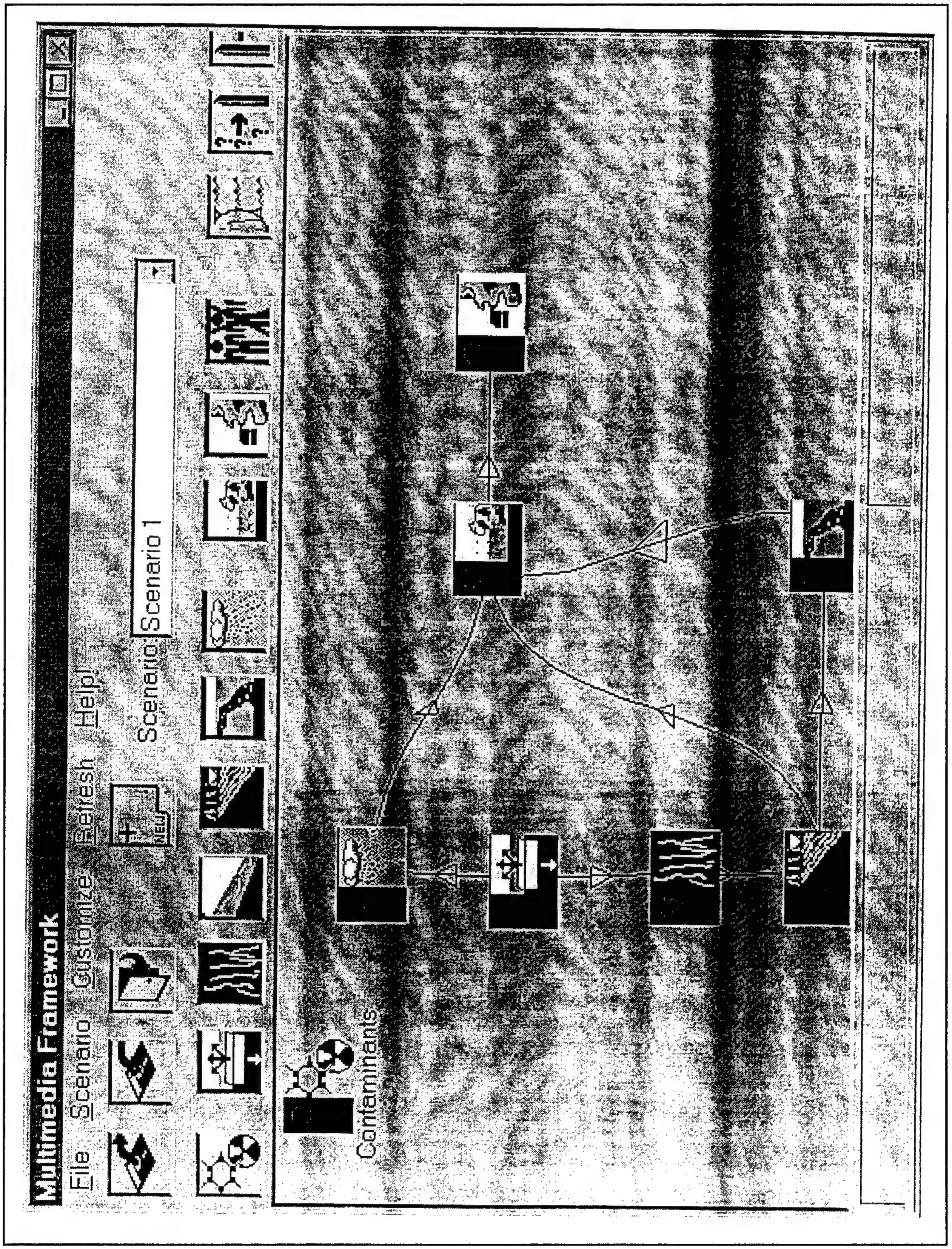
Multimedia Framework
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Scenario: Scenario 1
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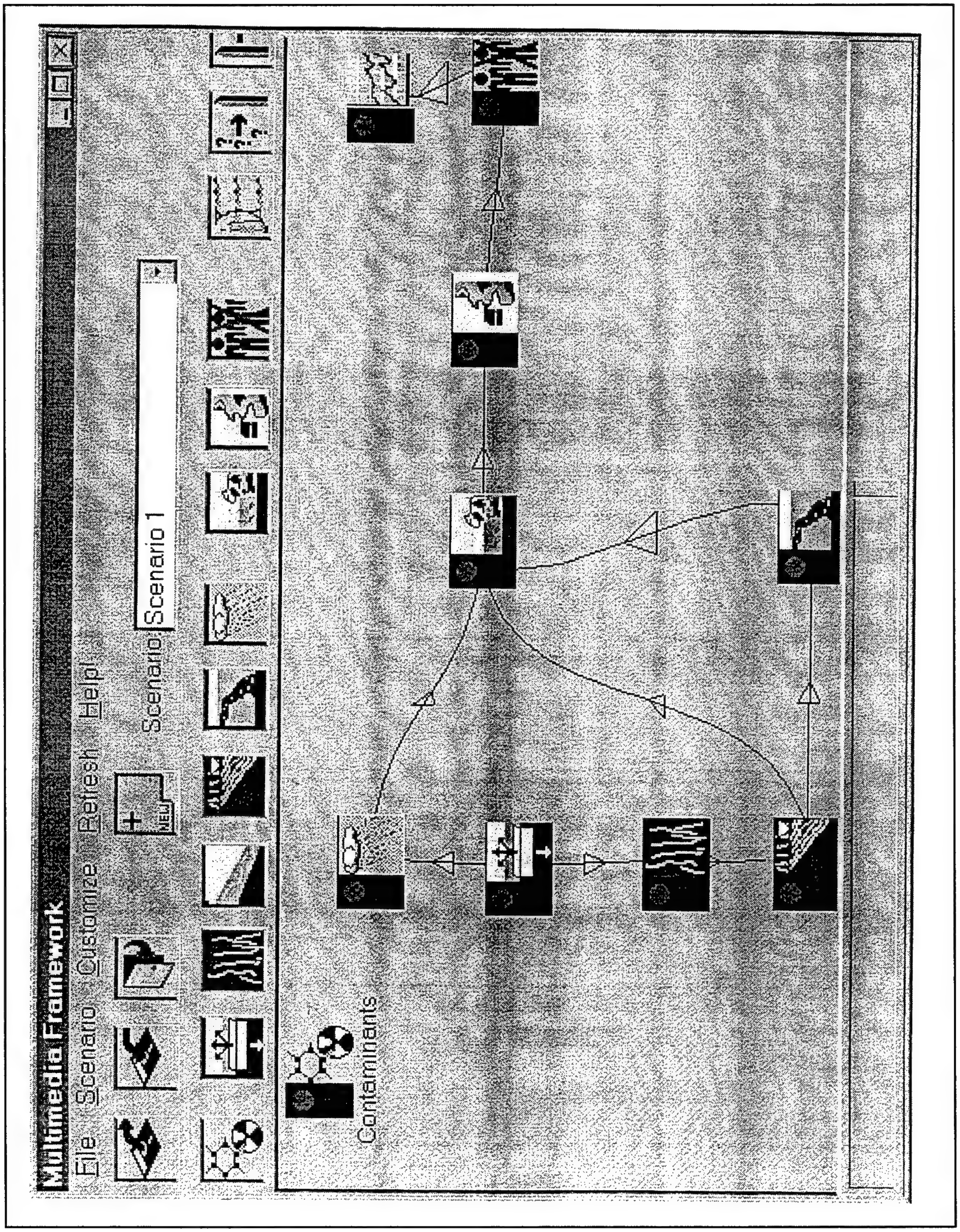

Multimedia Framework
File Scenario Customize Refresh Help
Scenario: Scenario 1
Contaminants

Summary

- Allows users to implement preferred models
- Allows users to link preferred models to and communicate with other models
- Allows for a standard, base set of models (Regulatory Review)
- Maintains Legacy of models
- Provides a "plug-and-play" environment
- Helps the user with the conceptual site model

Battelle

Appendix D Dredged Material Modeling—Risk-Based Concepts

This appendix contains the presentation documents for “Dredged Material Modeling—Risk-Based Concepts” by Paul Schroeder - U.S. Army Engineer Waterways Experiment Station.

Dredged Material Modeling -- Risk Concepts

Paul R. Schroeder

Environmental Laboratory
USAE Waterways Experiment Station

Introduction

- Technical evaluation of the environmental acceptability of dredged material disposal is an effects-based process compatible with risk assessment.
- Computer programs and databases have been developed to aid in the evaluation:
  - ADDAMS
  - DANNY (Open water disposal data acquisition network and management tools/models)
  - E2D2

Technical Framework

- Effects testing coupled with pathway modeling to predict exposure
  - Upland Disposal
    - Effluent
    - Runoff
    - Leachate
    - Volatilization
    - Plant uptake
    - Animal uptake
  - Open Water
    - Water column
    - Benthic
- Multi-tiered, screening level to ....
- Comparison of exposure with toxicity criteria or effect level instead of risk computation

Topics of Discussion

- USCOE/USEPA Technical Framework
- ADDAMS and E2D2
- User Needs

ADDAMS (Automated Dredging and Disposal Alternatives Modeling System)

- PC-based system for DOS and Windows 95
- Collection of simple, nonintegrated, computerized tools and models for dredged material management and environmental effects evaluations
- Collection of 16 modules
- Predominantly stand-alone screening-level models linked under a common shell or menu
- Hardware and operating platform requirements restricted to availability of the masses (lowest common demoninator)

Example ADDAMS Application

Evaluation of Effluent Pathway from an Upland Confined Disposal Facility CDF--

- DYECON module to estimate CDF hydraulic efficiency
- SETTLE to analyze settling test data to estimate effluent suspended solids concentration using hydraulic efficiency
- EFQUAL to analyze modified elutriate test data to estimate effluent quality using effluent suspended solids and to compare with water quality criteria and predict dilution requirements
- LAT-E to analyze water column bioassay test data to estimate toxicity to compare with toxicity quality criteria and predict dilution requirements
- CDFATE to compute mixing zone size using dilution requirements

E2D2 (Environmental Effects Determination Database)

- Web based database of literature on environmental effects of contaminant residue in tissue of aquatic organisms
- Interpretation of bioaccumulation data to determine environmental significance in absence of criteria

User Needs

- Multi-tier
- Models of control measures and operational restrictions
- Common, consistent, simple user interface
- Data bases
- Documentation, support, and training
- Verification, validation, and endorsement
- Portability
- Easy access

Appendix E Bioaccumulation Modeling Concepts and Principles/Contemporary Issues

This appendix contains the presentation documents for "Bioaccumulation Modeling Concepts and Principles/Contemporary Issues" by Bob Thomann - Manhattan College. Complete information for references cited in this appendix was provided in handouts at the time of the workshop.

RELATIONSHIP FOR ANY ANIMAL, ANYWHERE (FISH, HUMAN, EAGLE) IN AQUATIC SYSTEM

GRAMS CHEMICAL/DAY

ALLOWABLE DOSE = INTAKE FROM WATER INGESTION + INTAKE FROM FOOD/PREY INGESTION

$$D = I * c + F * \nu$$

$I * c$: Water Intake (L/d) * "Avail." Conc.(g/L)

$F * \nu$: Food Intake (gfd/d)* Food Chem. Conc. (g chem/g fd)

FOR WATER QUALITY CRITERIA:

NEED A RELATIONSHIP BETWEEN CHEMICAL CONCENTRATION IN FOOD (PREY) AND CHEMICAL CONCENTRATION IN WATER

INITIALLY

ASSUMED FOOD CHAIN BIOACCUMULATION OF CHEMICAL WAS NOT SIGNIFICANT

DEFINE BIOCONCENTRATION FACTOR **(BCF)** AS RATIO CHEMICAL CONC. IN FOOD TO WATER CONC. **<u>FOR EXPOSURE TO WATER ONLY</u>**

MAJOR ADVANTAGES

1. BCF EASILY DETERMINED IN LABORATORY UNDER CONTROLLED CONDITIONS WITH "STANDARD" (SMALL) FISH

2. NOT DEPENDENT ON SITE CHARACTERISTICS

THEN THE WATER QUALITY CRITERION IS :

$$\text{WQC: } c(\text{allow}) = \frac{D(\text{allow})}{(I + F * BCF)}$$

D(allow): from Dose/Response,
I & F: from general intake/consumption data
BCF: from lab experiments

NEAT & CLEAN

SITE INDEPENDENT
NATIONAL WQC POSSIBLE

WQC:
c(allow)

PHYSIO-CHEMICAL FATE/TRANSPORT MODEL:
DILUTION, PARTITIONING, BIOAVAILABILITY, KINETICS

WASTE LOAD ALLOCATION

CRITERIA:
SITE INDEPENDENT

WASTE LOAD ALLOCATION:
SITE DEPENDENT

NOW THE WATER QUALITY CRITERION IS :

$$\text{WQC: } c(\text{allow}) = \frac{D(\text{allow})}{(I + F*BAF)}$$

BAF IS DEPENDENT ON FOOD WEB

NOT SO NEAT & CLEAN

MORE SITE DEPENDENT

NATIONAL WQC POSSIBLE ONLY FOR GENERIC FOOD WEB

FRC: Allow. Food Conc.

FOOD WEB MODEL: UPTAKE, INGESTION, DEPURATION, METABOLISM

PHYSIO-CHEMICAL FATE/TRANSPORT MODEL: DILUTION, PARTITIONING, BIOAVAILABILITY, KINETICS

CRITERIA: SITE INDEPENDENT

WASTE LOAD ALLOCATION: SITE DEPENDENT

WASTE LOAD ALLOCATION

HOW TO DETERMINE ALLOWABLE WASTE LOAD ALLOCATION OF CHEMICALS THAT MAY BIOACCUMULATE?

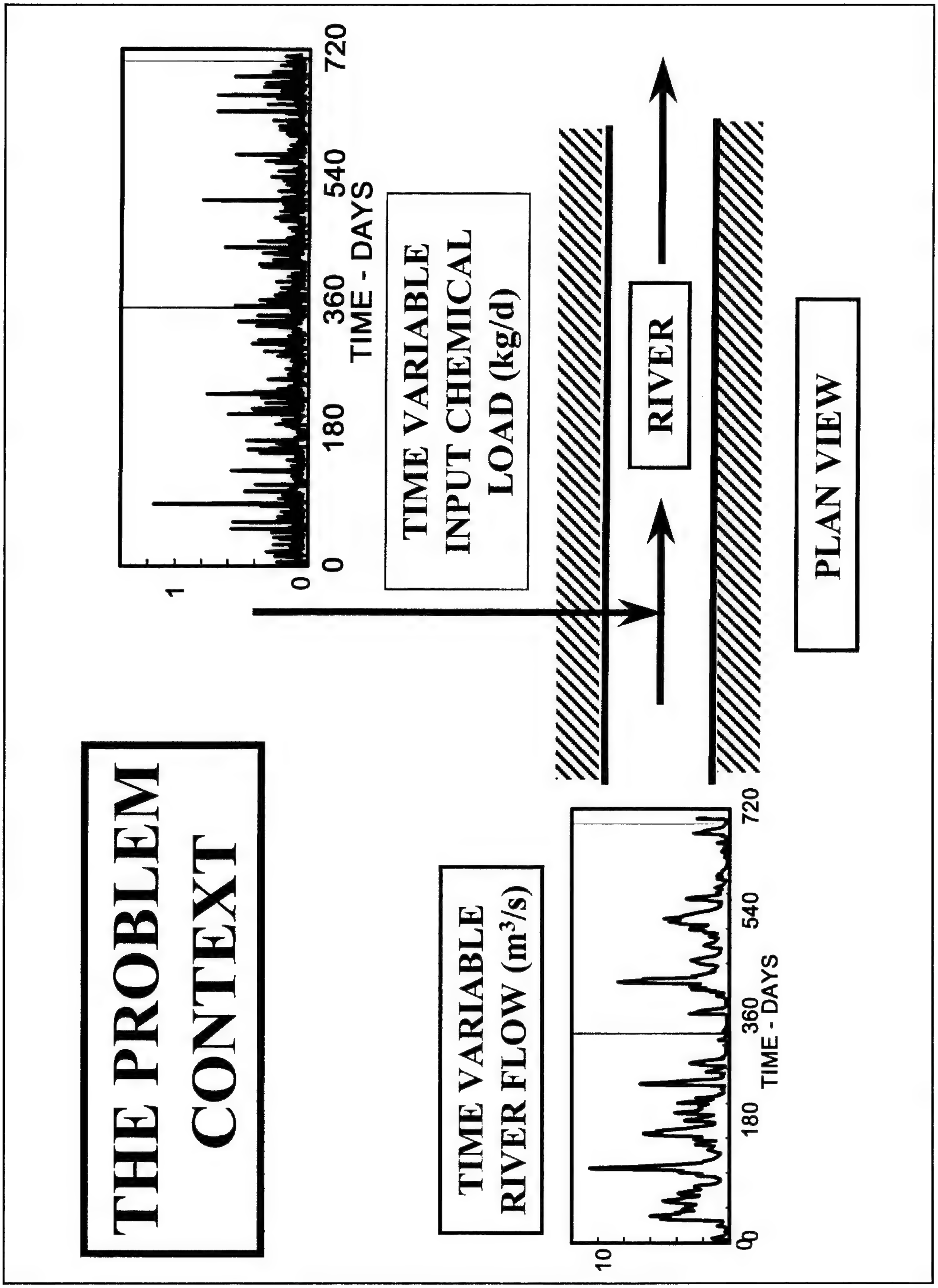
- **ISSUE**
  - **Time Variable** Load, Flow= time variable Water & Sediment Conc. = time variable Organism Tissue Conc.
  - **Bioaccumulation Factor (BAF)**

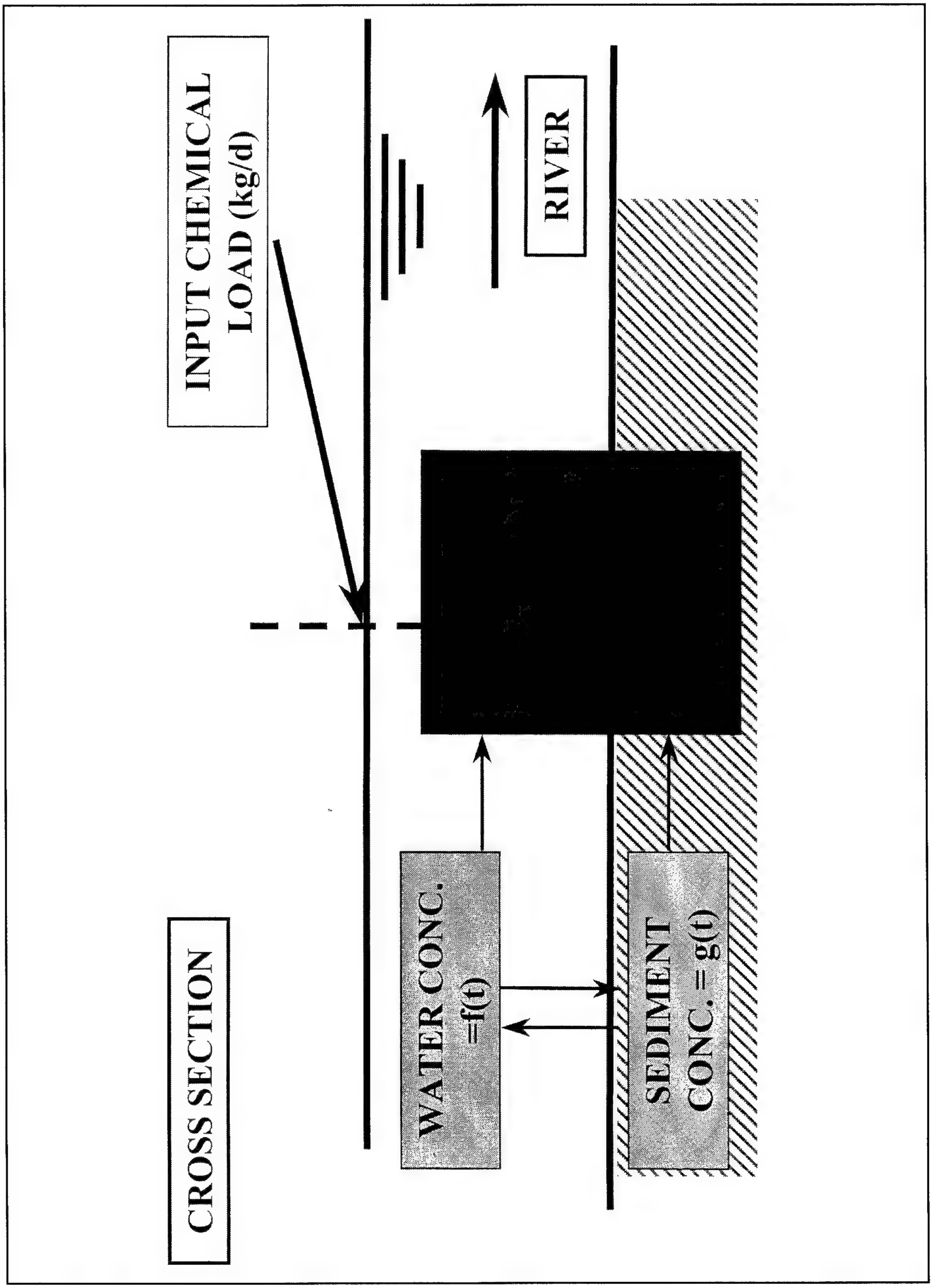
    = Tissue (t)/Water (t);

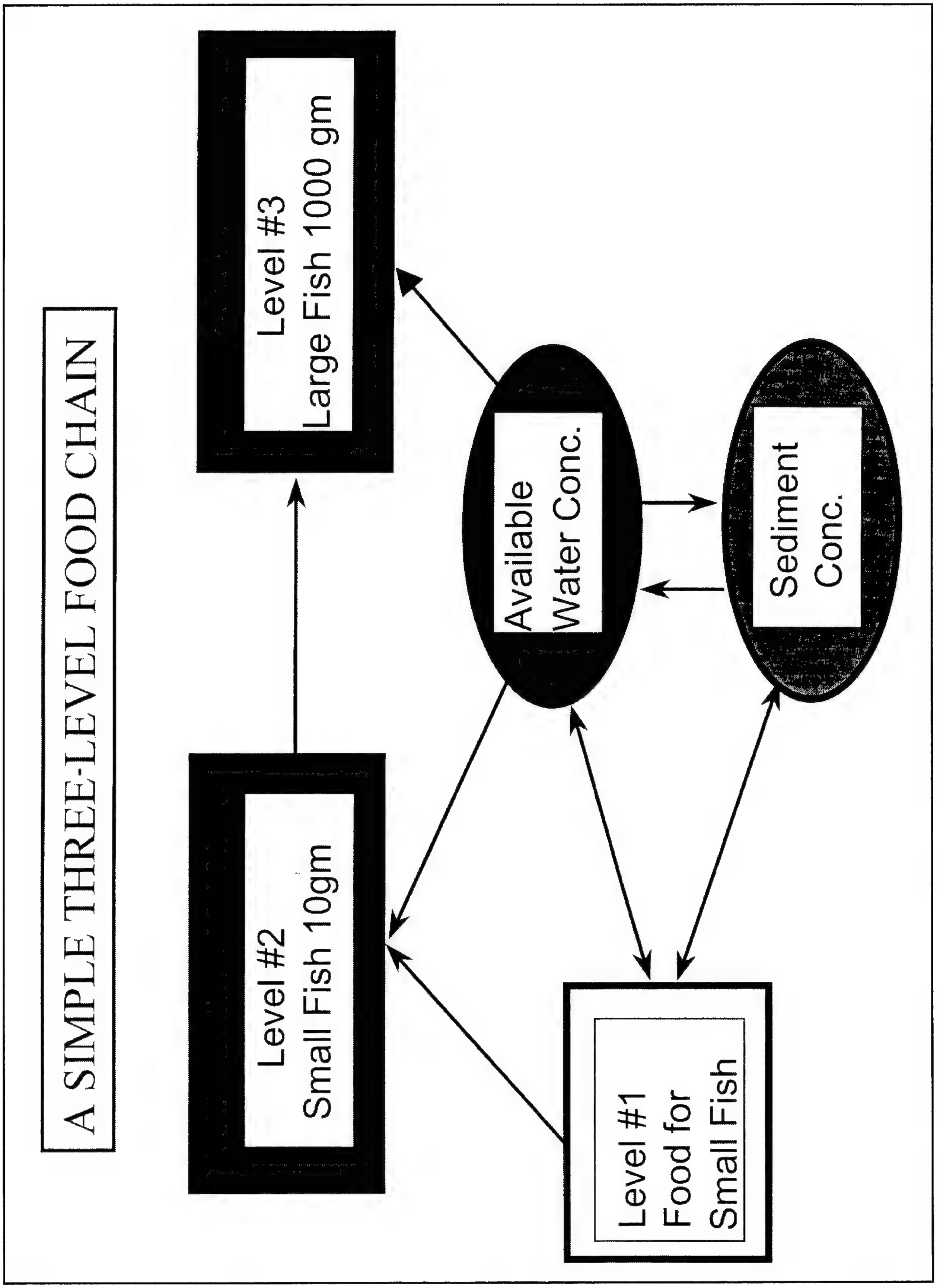
    useful for **Steady State** or slowly varying evaluations.

PROPOSED APPROACH

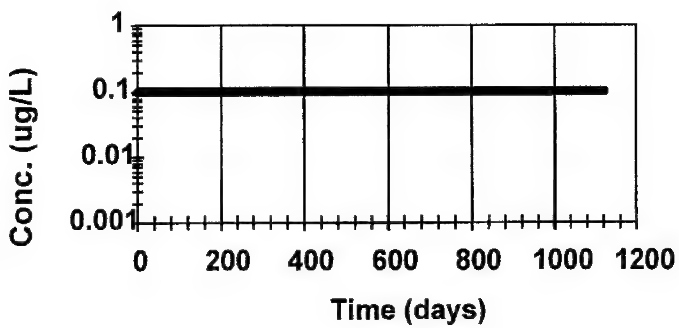
- REGULATE ON ALLOWABLE TISSUE CONCENTRATION @ ASSIGNED FREQUENCY OF EXCEEDANCE PERCENTILE
- DETERMINE ALLOWABLE FREQUENCY DISTRIBUTION OF CHEMICAL INPUT LOAD


THE PROBLEM CONTEXT
TIME VARIABLE INPUT CHEMICAL LOAD (kg/d)
1
0
0
180
360
540
720
TIME - DAYS
RIVER
PLAN VIEW
TIME VARIABLE RIVER FLOW (m3/s)
10
0
0
180
360
540
720
TIME - DAYS

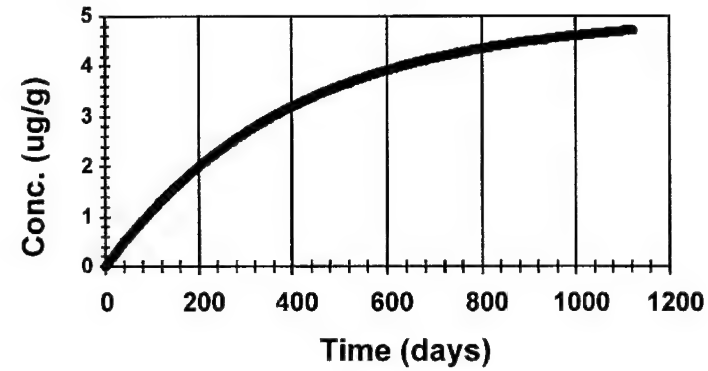

CROSS SECTION
INPUT CHEMICAL LOAD (kg/d)
RIVER
WATER CONC. =f(t)
SEDIMENT CONC. = g(t)


A SIMPLE THREE-LEVEL FOOD CHAIN
Level #3
Large Fish 1000 gm
Level #2
Small Fish 10gm
Available
Water Conc.
Sediment
Conc.
Level #1
Food for
Small Fish

WATER CONCENTRATION



LEVEL #3 - LARGE FISH



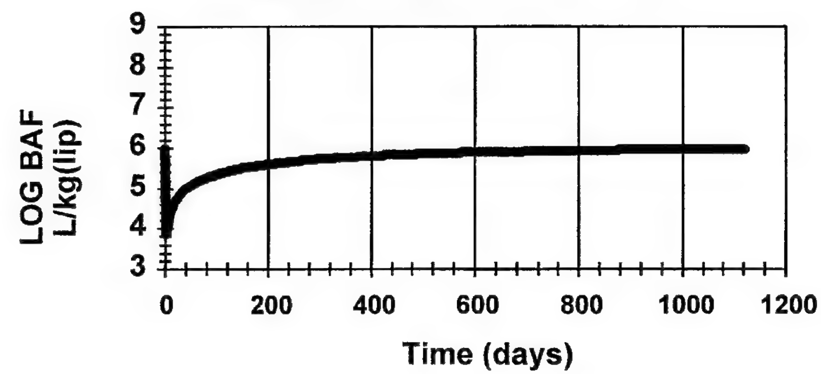
LOG K_{ow} = 6.0

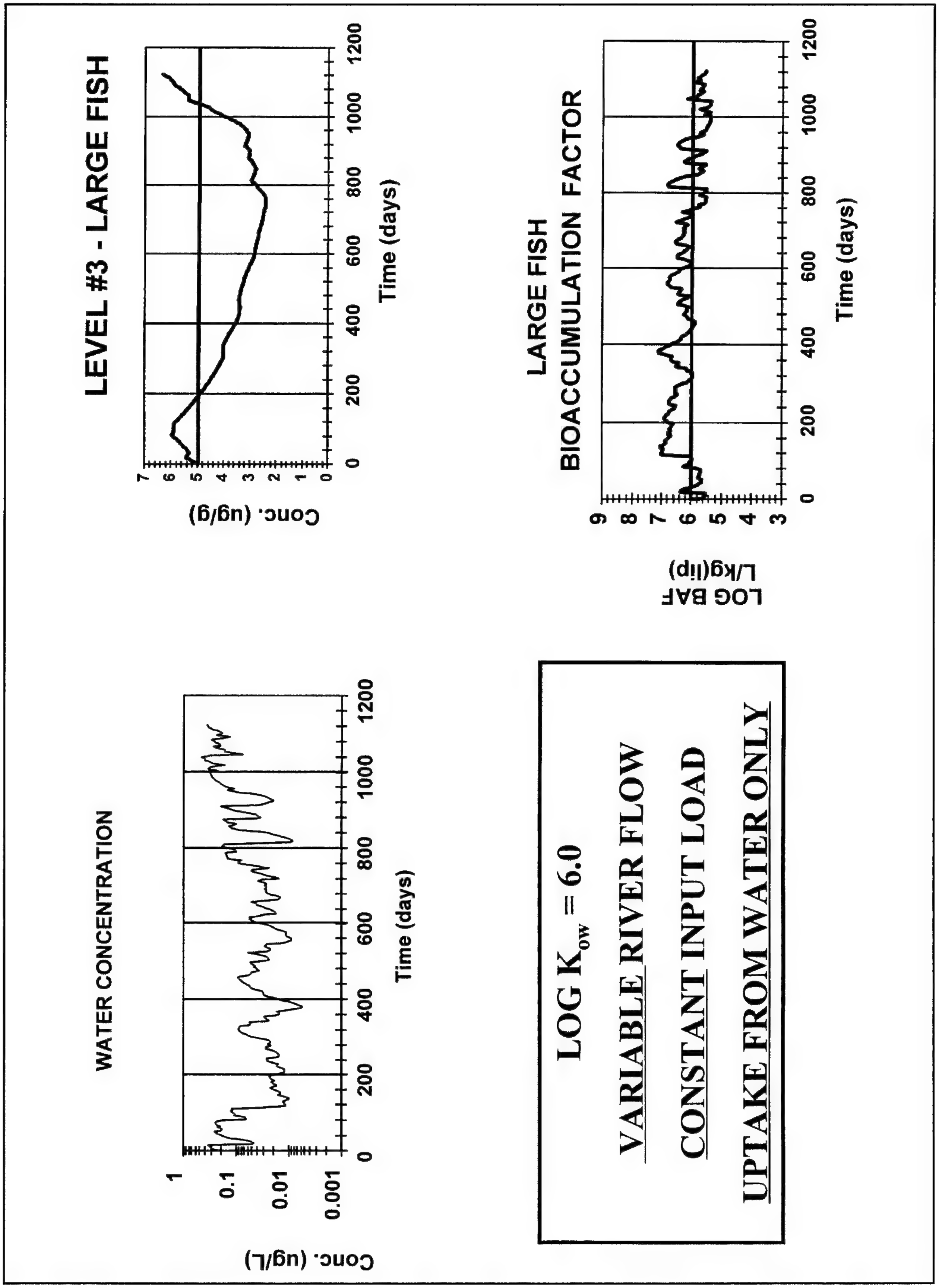
<u>CONSTANT</u> RIVER FLOW

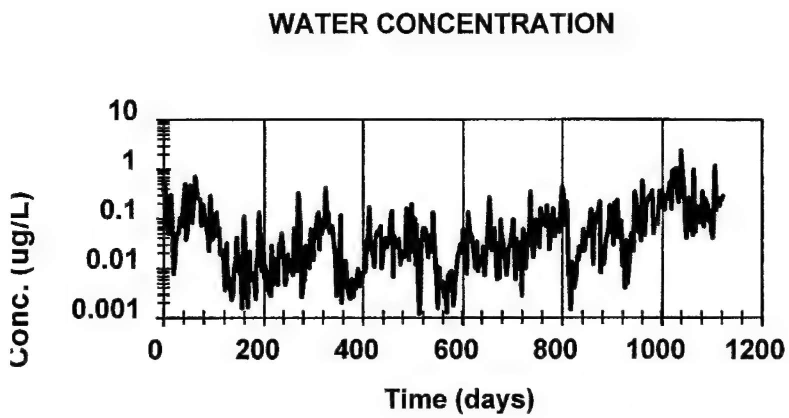
<u>CONSTANT</u> INPUT LOAD

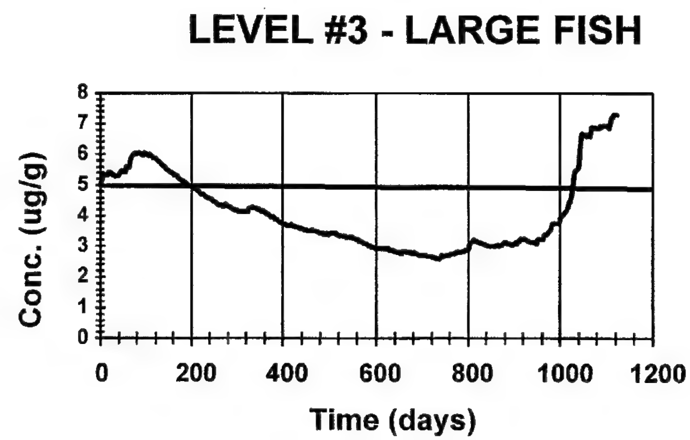
<u>UPTAKE FROM WATER ONLY</u>

LARGE FISH
BIOACCUMULATION FACTOR




WATER CONCENTRATION
Conc. (ug/L)
1
0.1
0.01
0.001
0
200
400
600
800
1000
1200
Time (days)
LEVEL #3 - LARGE FISH
Conc. (ug/g)
7
6
5
4
3
2
1
0
Time (days)
LOG K_{ow} = 6.0
VARIABLE RIVER FLOW
CONSTANT INPUT LOAD
UPTAKE FROM WATER ONLY
LARGE FISH
BIOACCUMULATION FACTOR
LOG BAF
L/kg(lip)
9
8
7
6
5
4
3
Time (days)



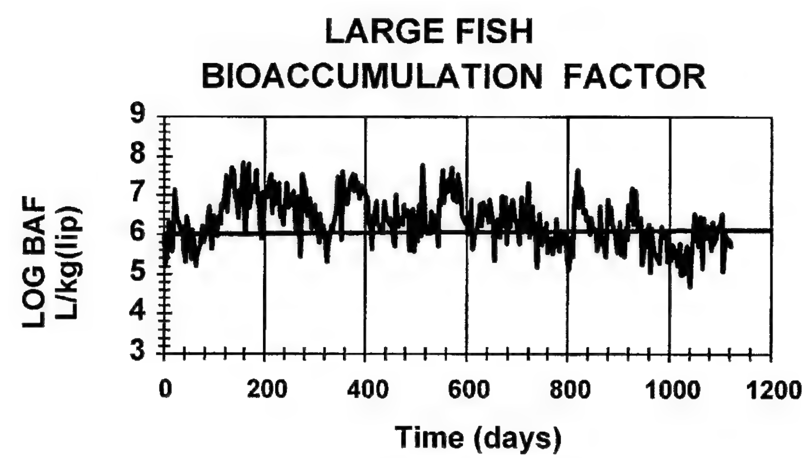


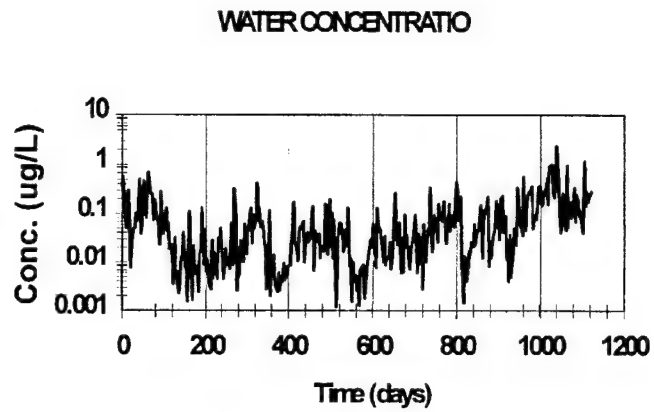
LOG K_{ow} = 6.0

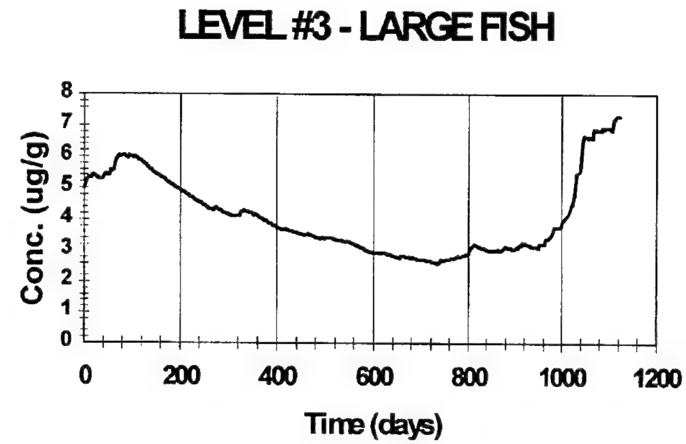
<u>VARIABLE</u> RIVER FLOW

<u>VARIABLE</u> INPUT LOAD

<u>UPTAKE FROM WATER ONLY</u>





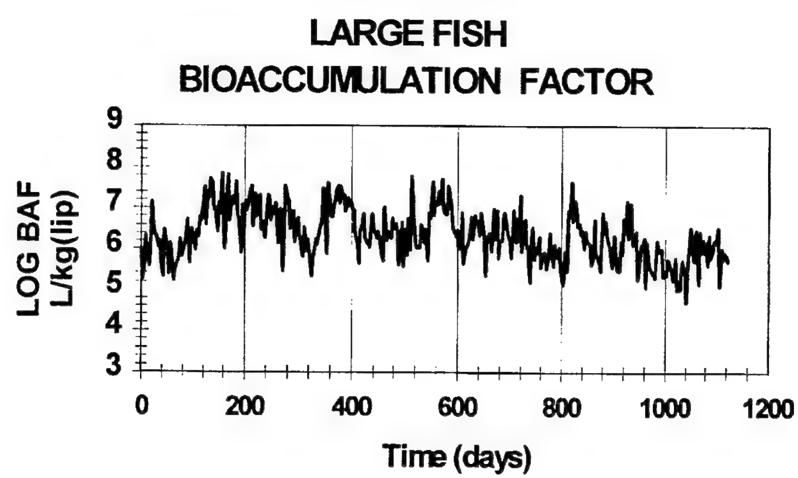


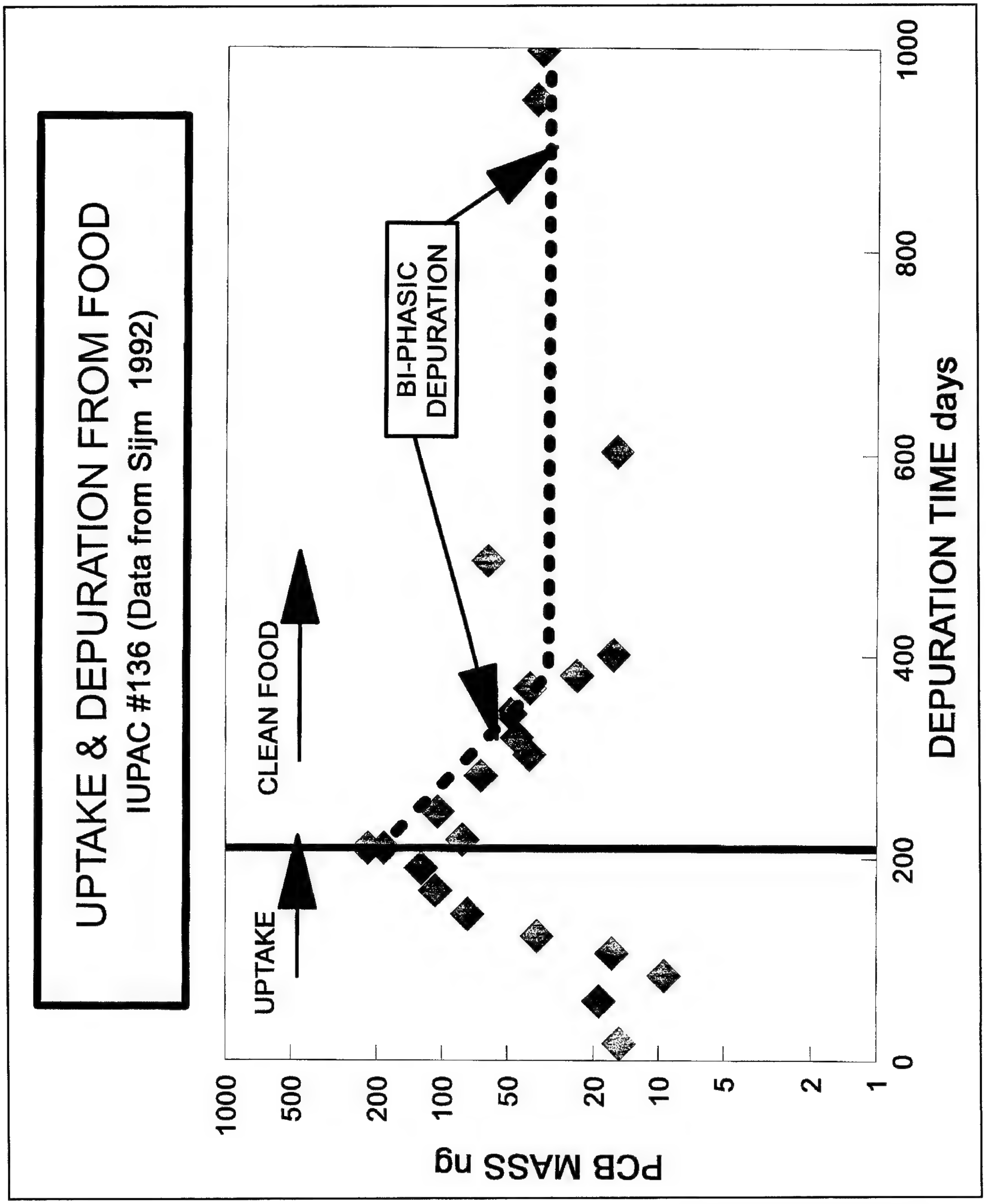
LOG K_{ow} = 6.0

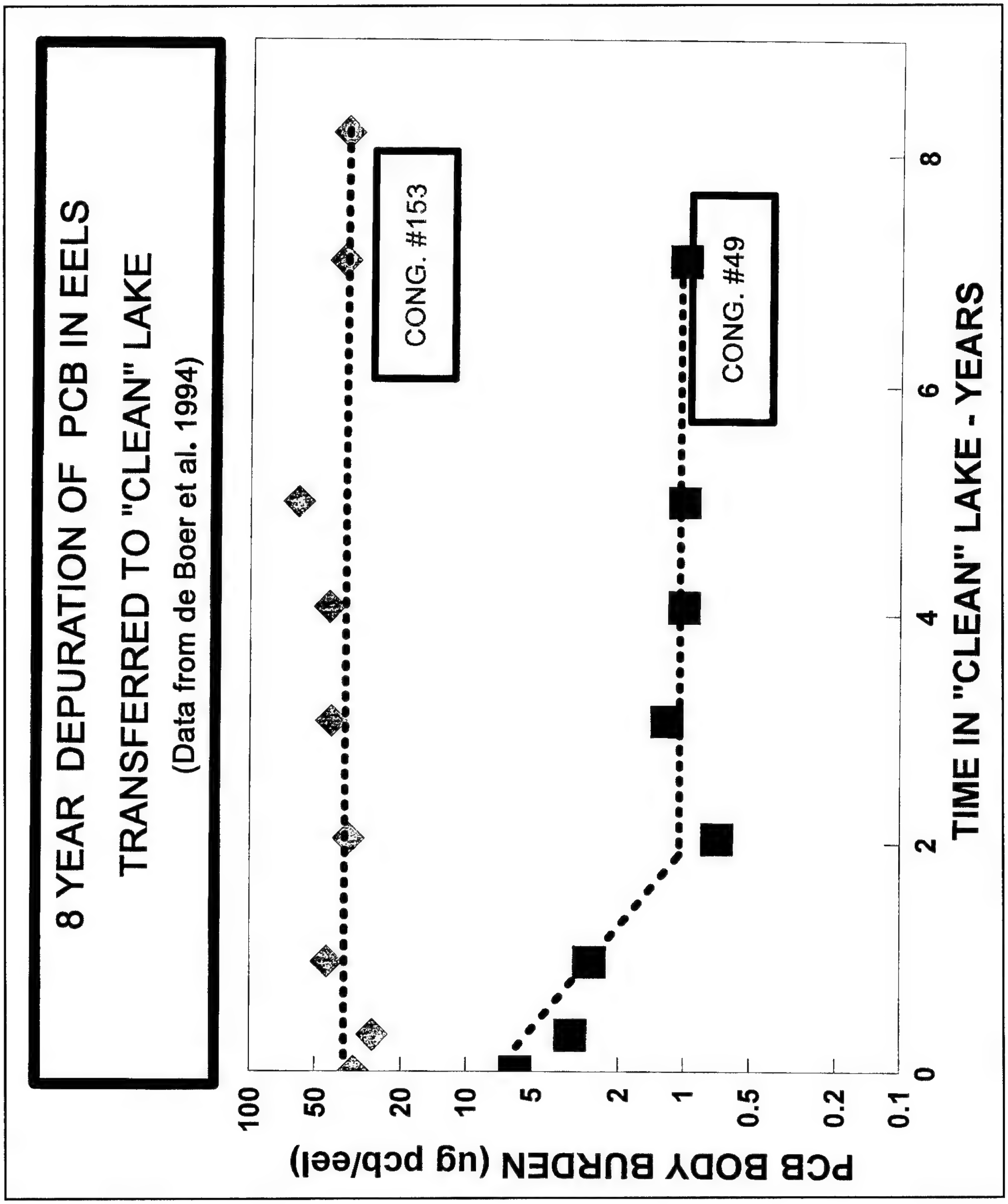
VARIABLE RIVER FLOW

CONSTANT INPUT LOAD

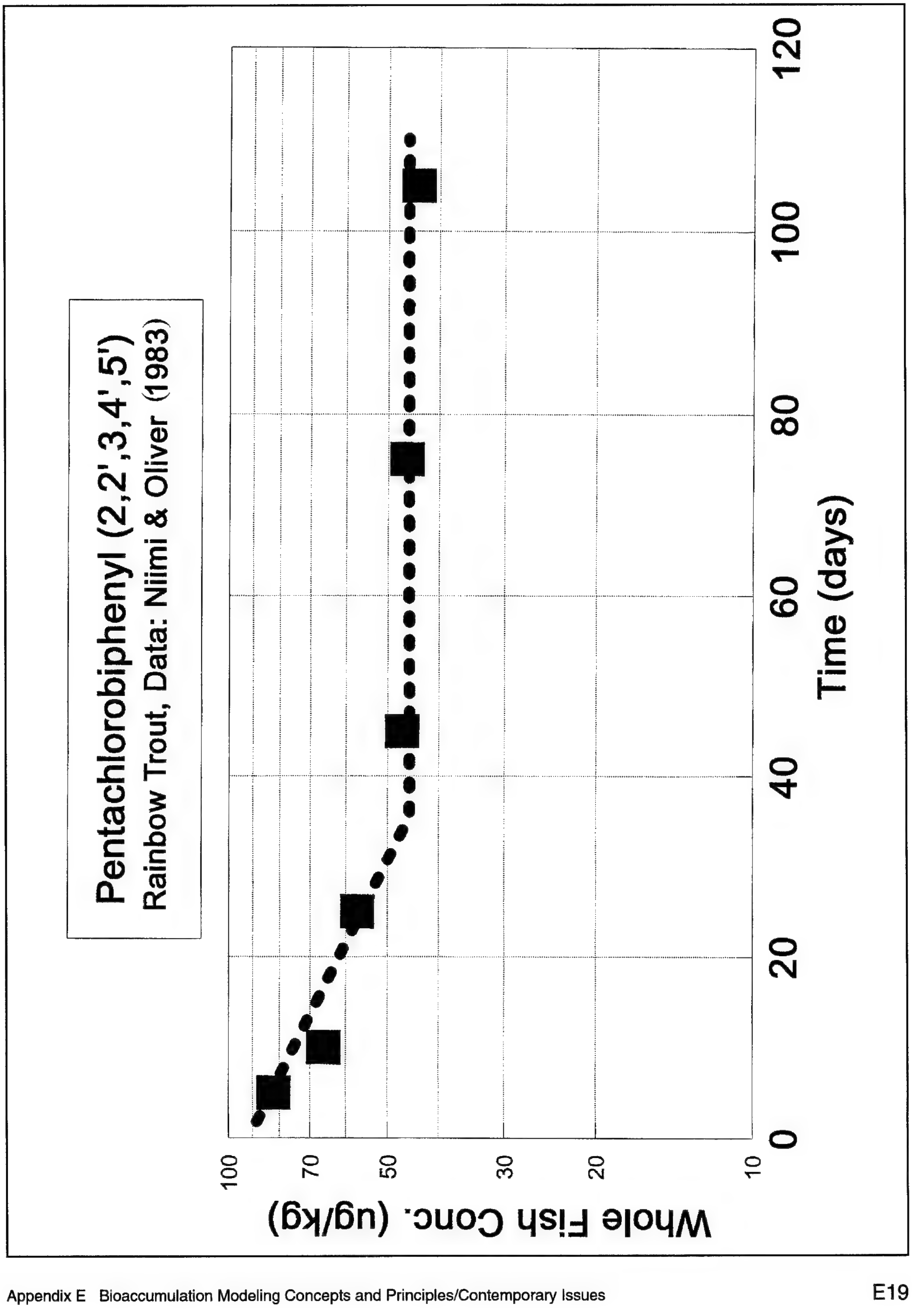
UPTAKE FROM WATER ONLY

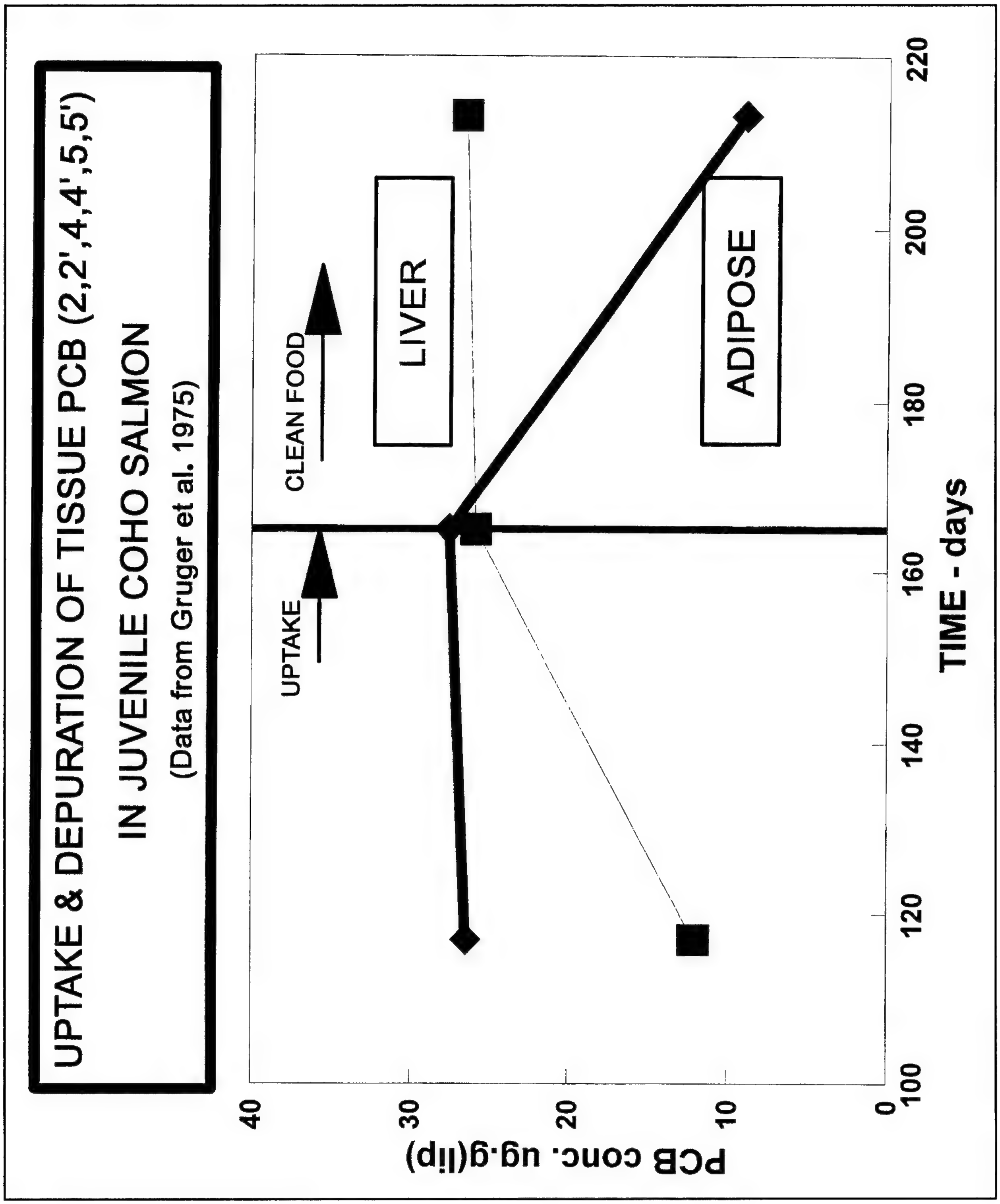


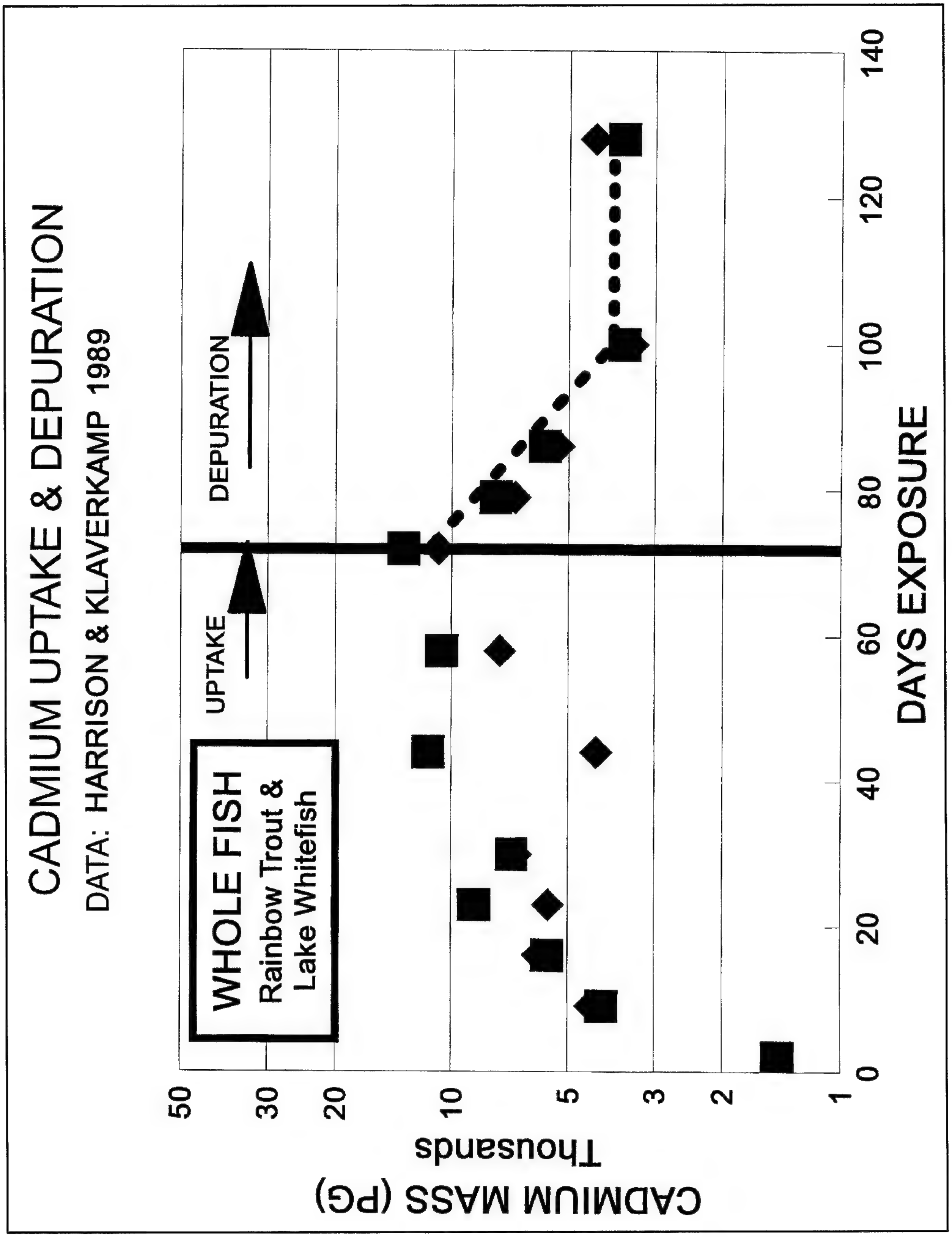

UPTAKE & DEPURATION FROM FOOD
IUPAC #136 (Data from Sijm 1992)
UPTAKE
CLEAN FOOD
BI-PHASIC DEPURATION
PCB MASS ng
1000
500
200
100
50
20
10
5
2
1
0
200
400
600
800
1000
DEPURATION TIME days

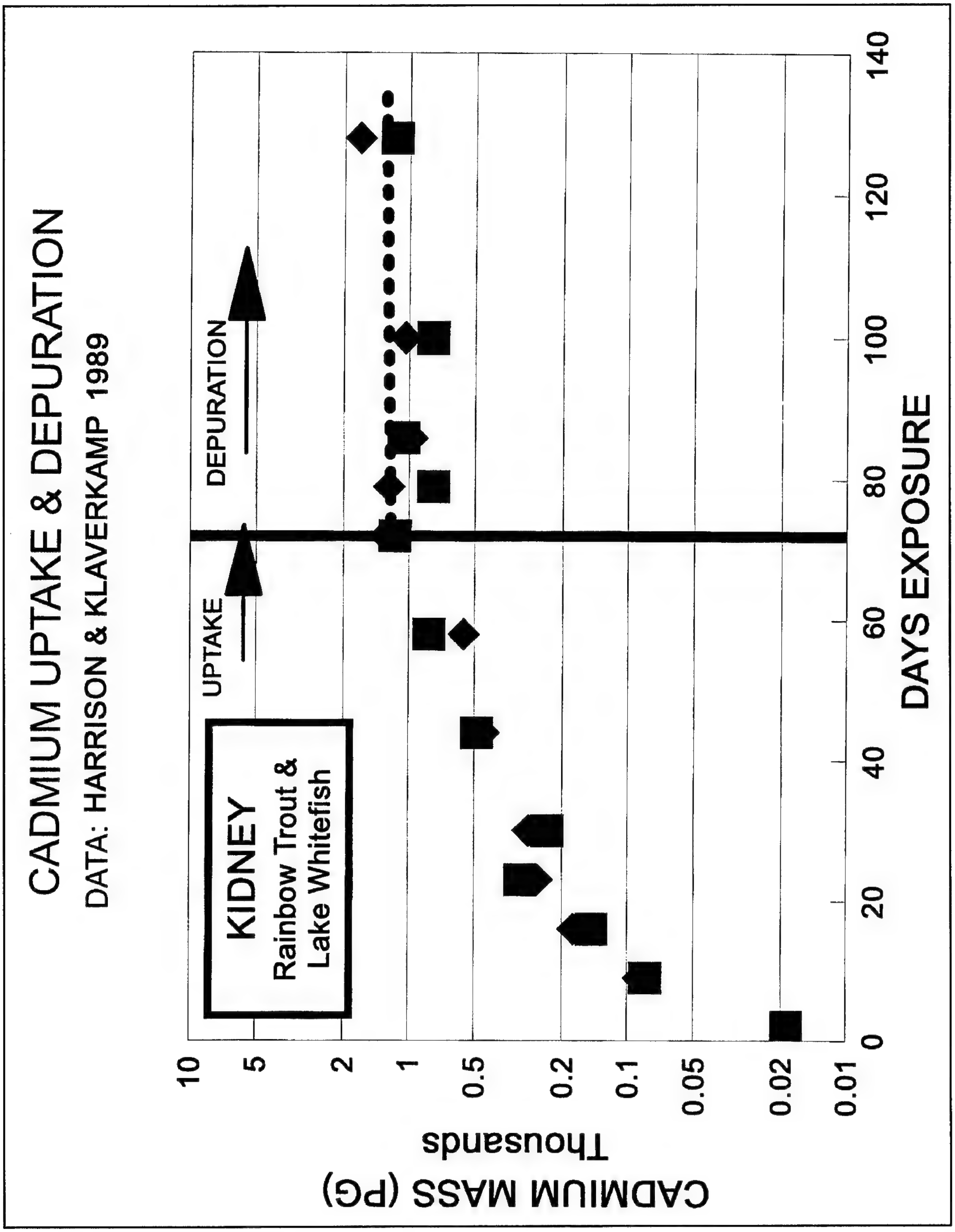


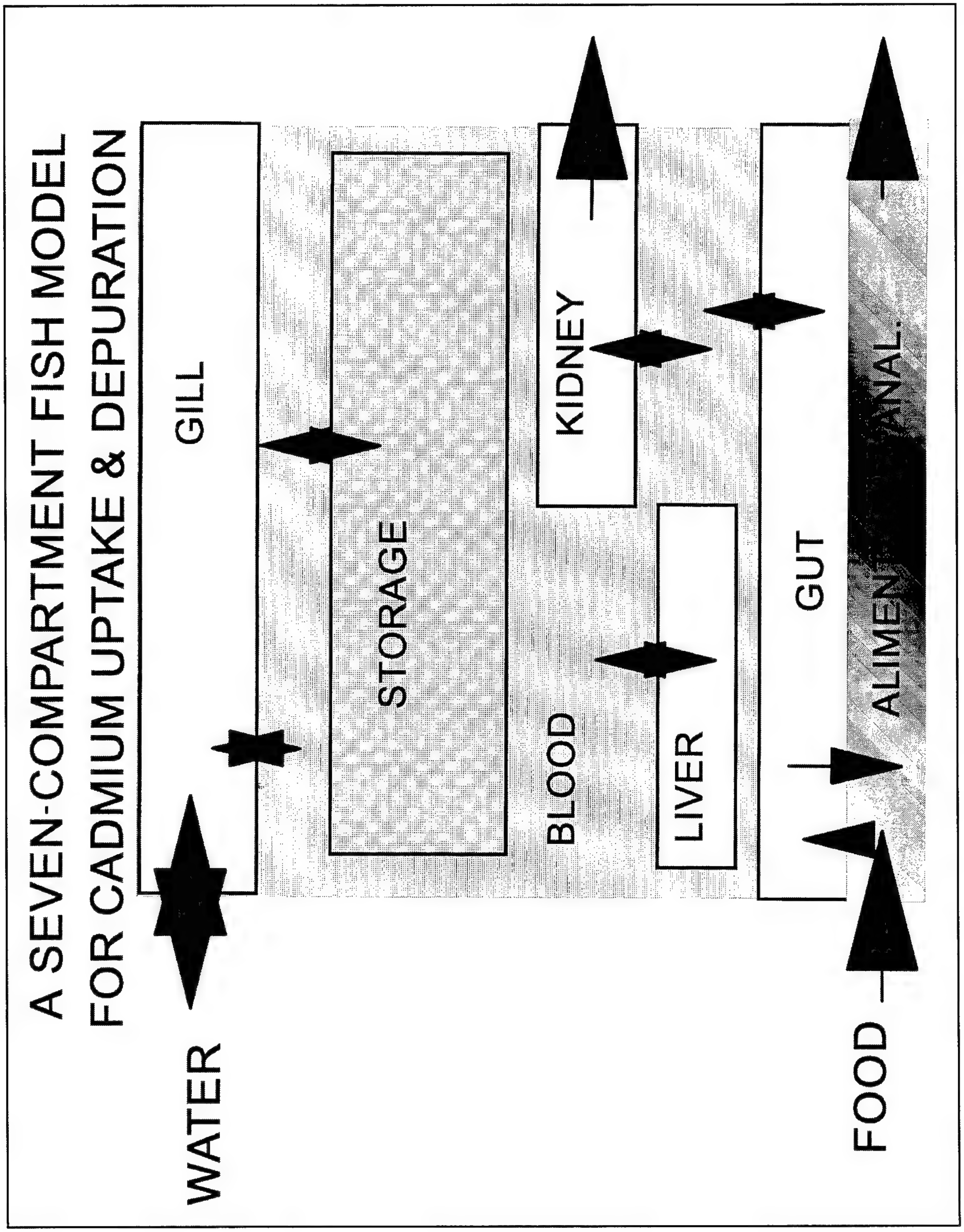
8 YEAR DEPURATION OF PCB IN EELS
TRANSFERRED TO "CLEAN" LAKE
(Data from de Boer et al. 1994)
CONG. #153
CONG. #49
PCB BODY BURDEN (ug pcb/eel)
100
50
20
10
5
2
1
0.5
0.2
0.1
0
2
4
6
8
TIME IN "CLEAN" LAKE - YEARS

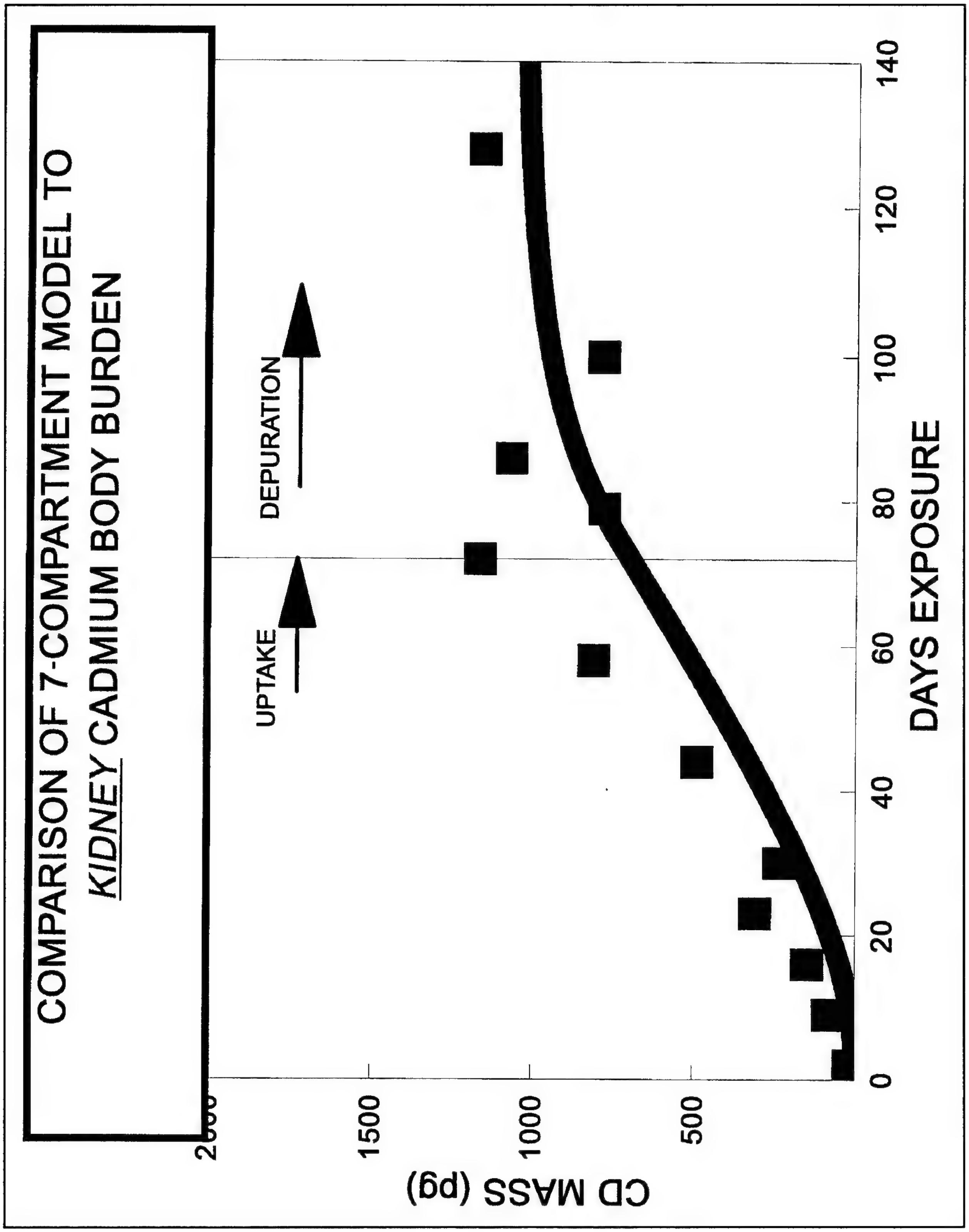

Pentachlorobiphenyl (2,2',3,4',5')
Rainbow Trout, Data: Niimi & Oliver (1983)
Whole Fish Conc. (ug/kg)
100
70
50
30
20
10
0
20
40
60
80
100
120
Time (days)

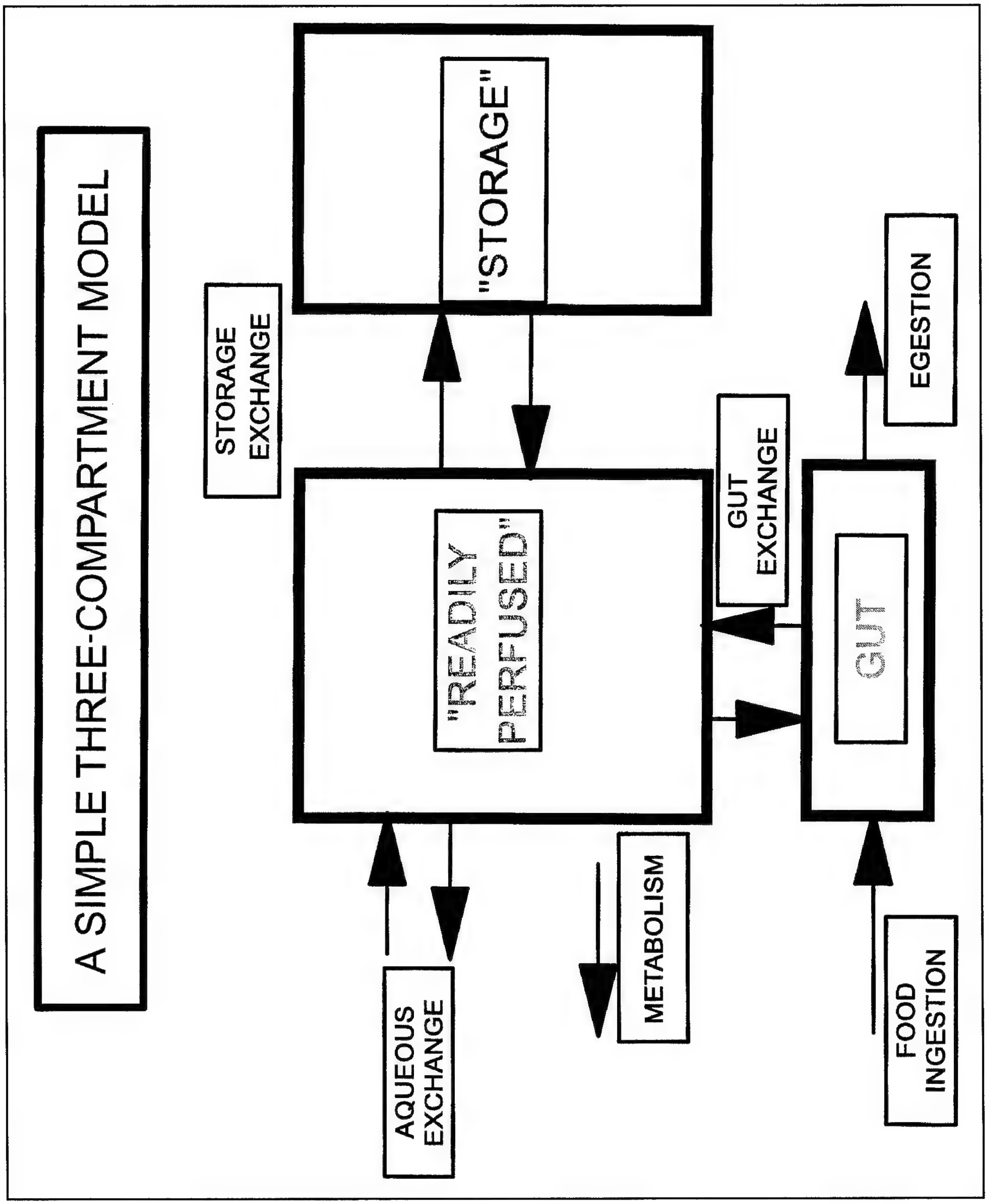

UPTAKE & DEPURATION OF TISSUE PCB (2,2',4,4',5,5')
IN JUVENILE COHO SALMON
(Data from Gruger et al. 1975)
UPTAKE
CLEAN FOOD
LIVER
ADIPOSE
PCB conc. ug.g(lip)
0
10
20
30
40
100
120
140
160
180
200
220
TIME - days

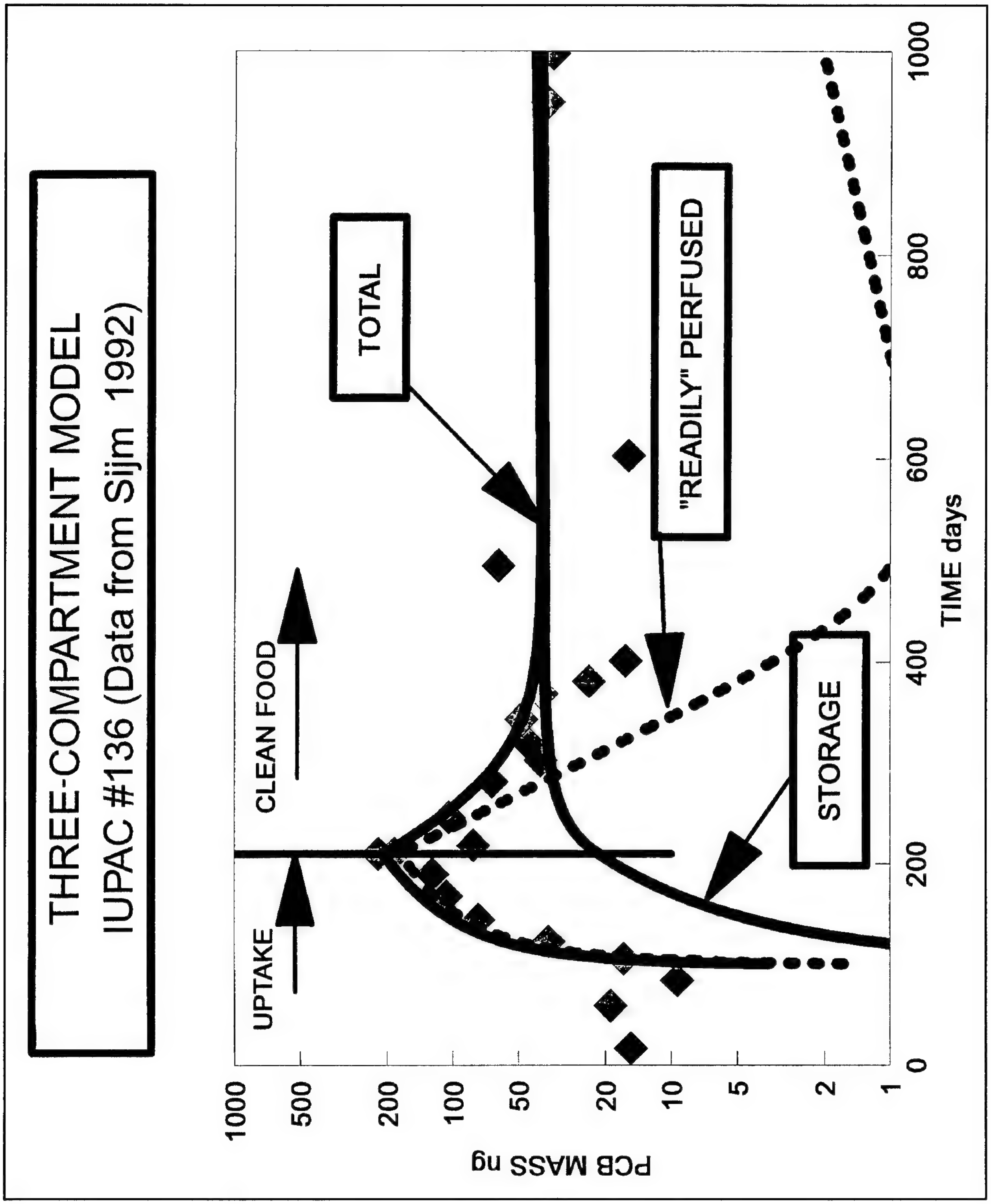

CADMIUM UPTAKE & DEPURATION
DATA: HARRISON & KLAVERKAMP 1989
WHOLE FISH
Rainbow Trout &
Lake Whitefish
UPTAKE
DEPURATION
CADMIUM MASS (PG)
Thousands
50
30
20
10
5
3
2
1
0
20
40
60
80
100
120
140
DAYS EXPOSURE


CADMIUM UPTAKE & DEPURATION
DATA: HARRISON & KLAVERKAMP 1989
KIDNEY
Rainbow Trout &
Lake Whitefish
UPTAKE
DEPURATION
CADMIUM MASS (PG)
Thousands
10
5
2
1
0.5
0.2
0.1
0.05
0.02
0.01
0
20
40
60
80
100
120
140
DAYS EXPOSURE


A SEVEN-COMPARTMENT FISH MODEL
FOR CADMIUM UPTAKE & DEPURATION
WATER
GILL
STORAGE
BLOOD
KIDNEY
LIVER
GUT
ALIMEN
ANAL.
FOOD


COMPARISON OF 7-COMPARTMENT MODEL TO
KIDNEY CADMIUM BODY BURDEN
UPTAKE
DEPURATION
CD MASS (pg)
DAYS EXPOSURE
2000
1500
1000
500
0
20
40
60
80
100
120
140


A SIMPLE THREE-COMPARTMENT MODEL
"STORAGE"
STORAGE EXCHANGE
"READILY PERFUSED"
GUT EXCHANGE
GUT
EGESTION
AQUEOUS EXCHANGE
METABOLISM
FOOD INGESTION



THREE-COMPARTMENT MODEL
IUPAC #136 (Data from Sijm 1992)
TOTAL
"READILY" PERFUSED
STORAGE
UPTAKE
CLEAN FOOD
PCB MASS ng
1000
500
200
100
50
20
10
5
2
1
0
200
400
600
800
1000
TIME days

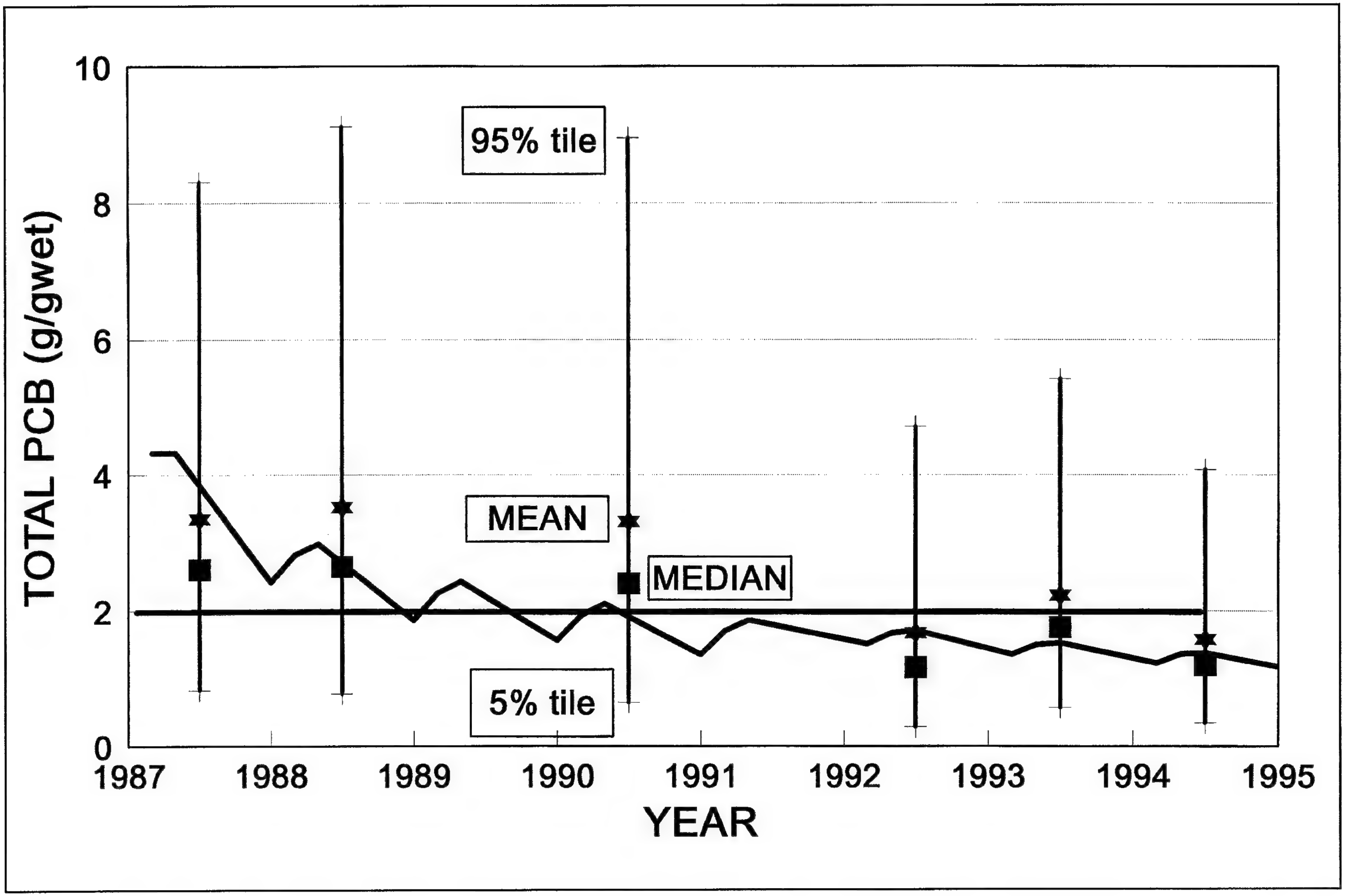


Figure 1. Comparison of original (as corrected) model projection (solid line) made in 1987 to observed data of striped bass (2-5 yr old), Food Web Region #2

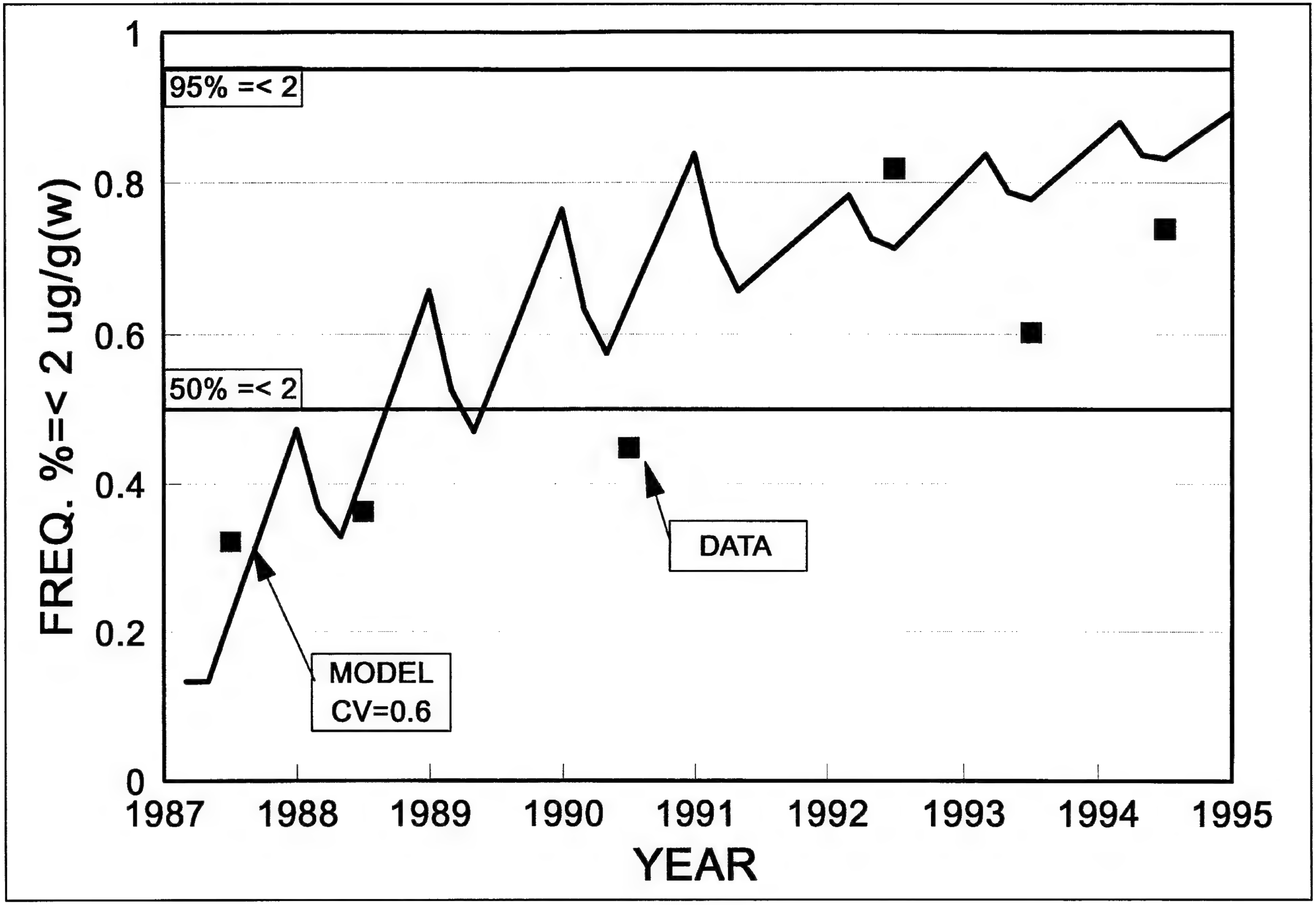


Figure 2. Comparison of observed vs. Model exceedance frequencies (%=< 2 ug/g). Striped bass (2-5 yr old), Food Web Region #2

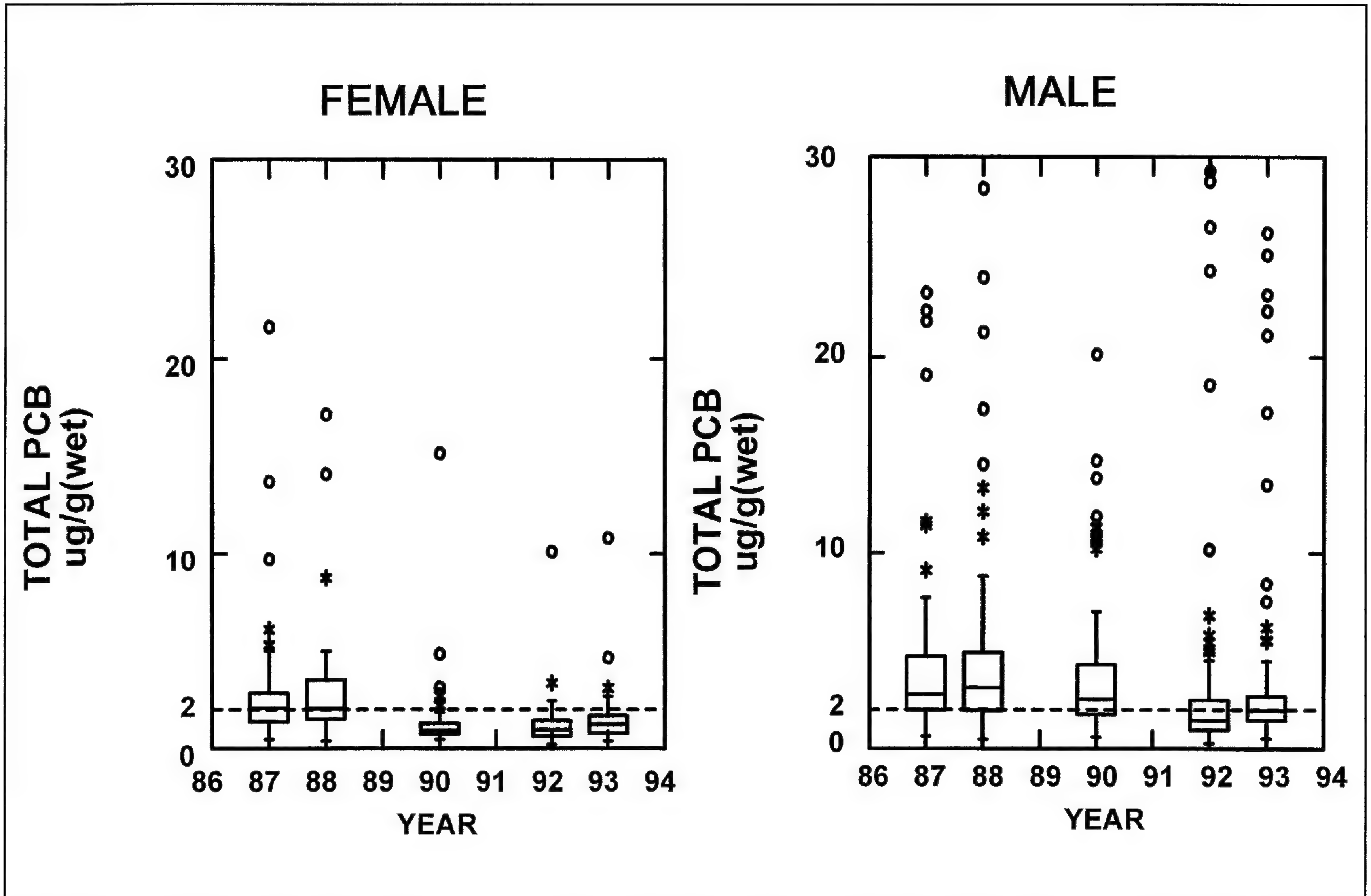


Figure 3. Variation in total PCB concentration in striped bass (2-5 yr old), Food Web Region #2. Line in box = 50th %tile, box boundaries = 25th and 75th %tile, symbols = outliers

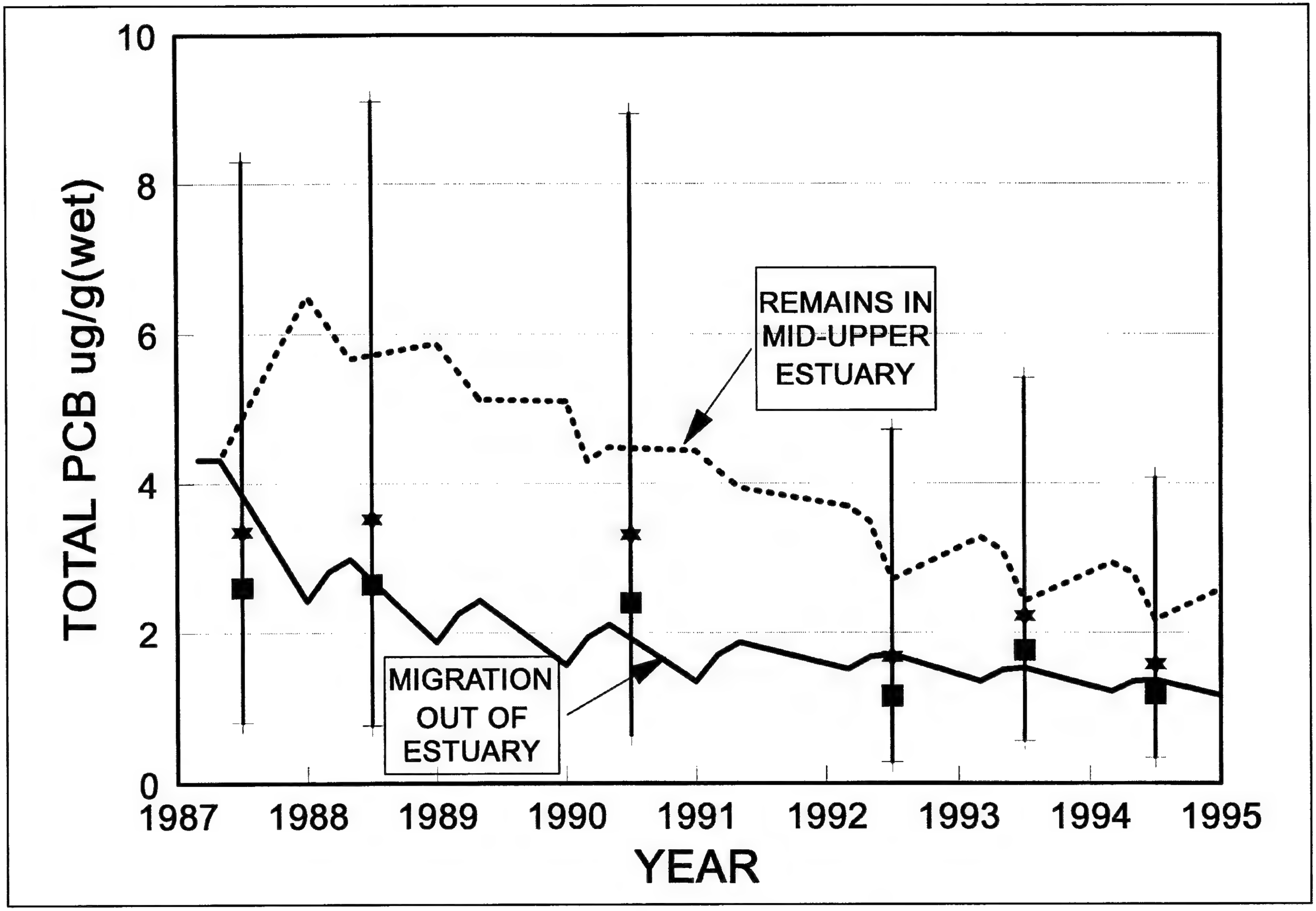


Figure 4. Calculated effect of varying migration of striped bass (2-5 yr old), Food Web Region #2

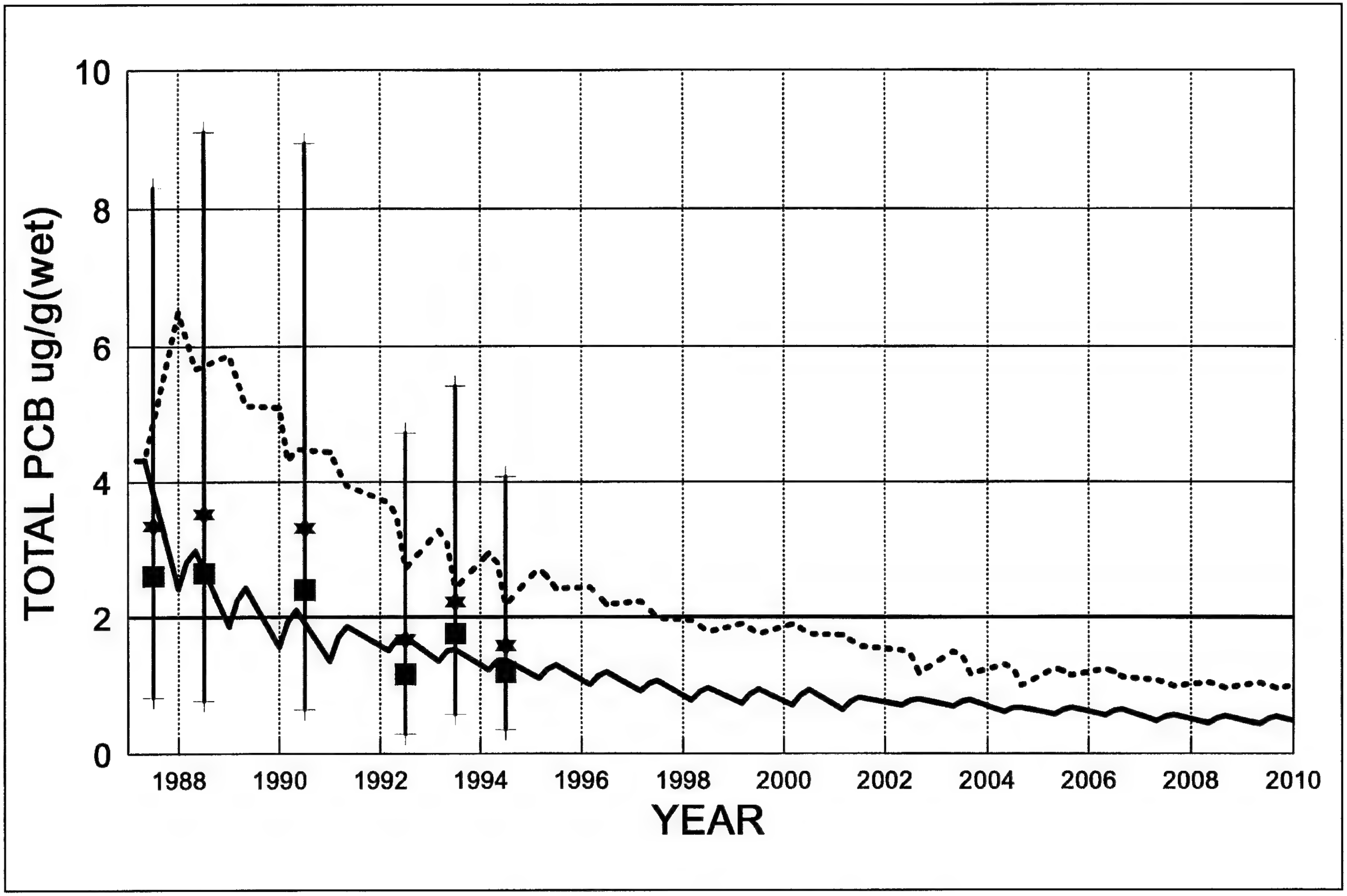


Figure 5. Long term model projection using original (1987) load projections with varying migration by striped bass. Solid line: striped bass migrates out of estuary; dashed line fish remains in estuary. Striped bass (2-5 yr old), Food Web Region #2

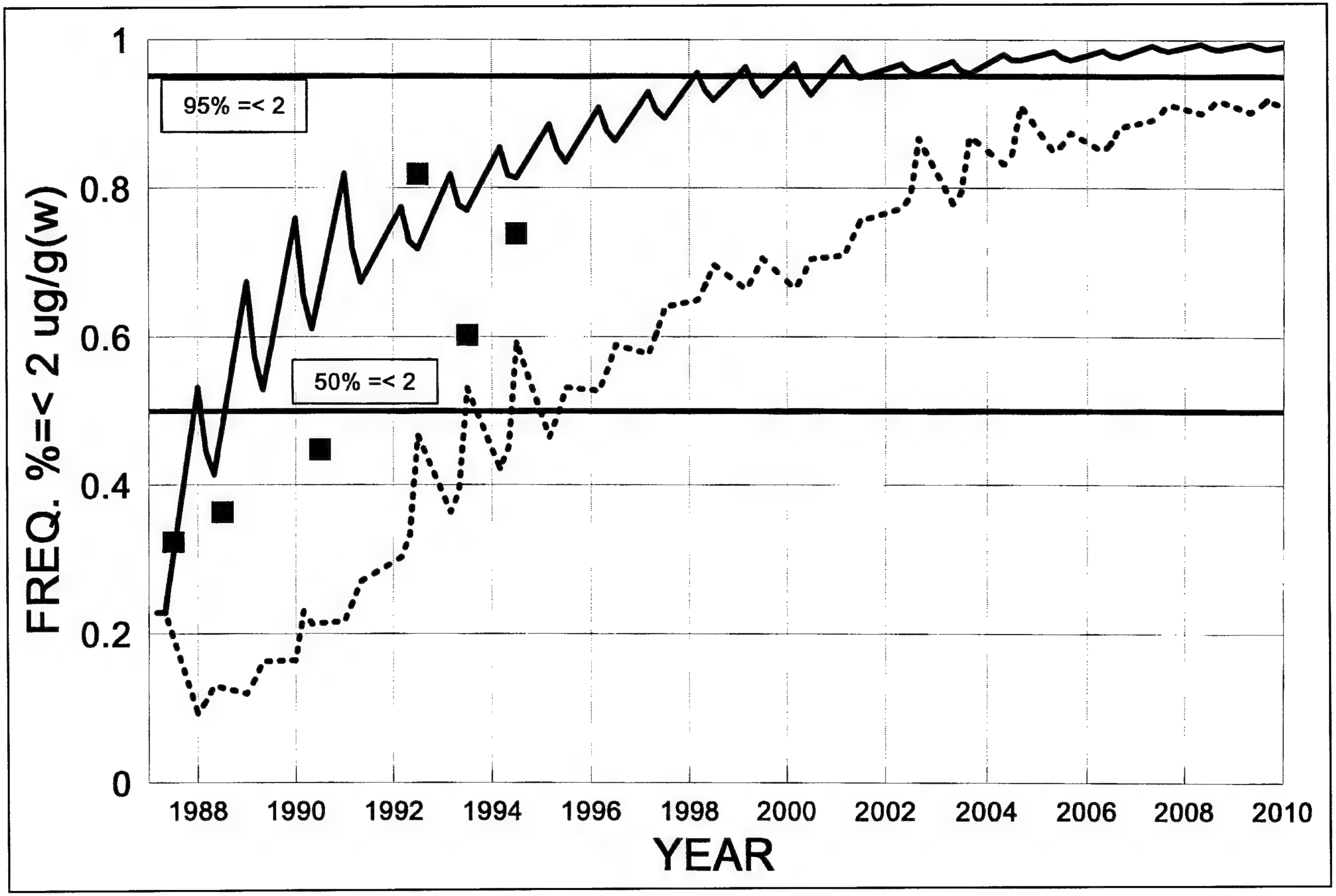


Figure 6. Long term model projection of frequency of striped bass =< 2 ug/g with varying migration by striped bass. Solid line: striped bass migrates out of estuary; dashed line: fish remains in estuary. Striped bass (2-5 yr old), Food Web Region #2

Appendix F
Ecosystem Models for Ecological Risk Analysis: From Single Species to Communities

This appendix contains the presentation documents for "Ecosystem Models for Ecological Risk Analysis: From Single Species to Communities" by Scott Ferson - Applied Biomathematics.

Adding Ecology to Ecotoxicology

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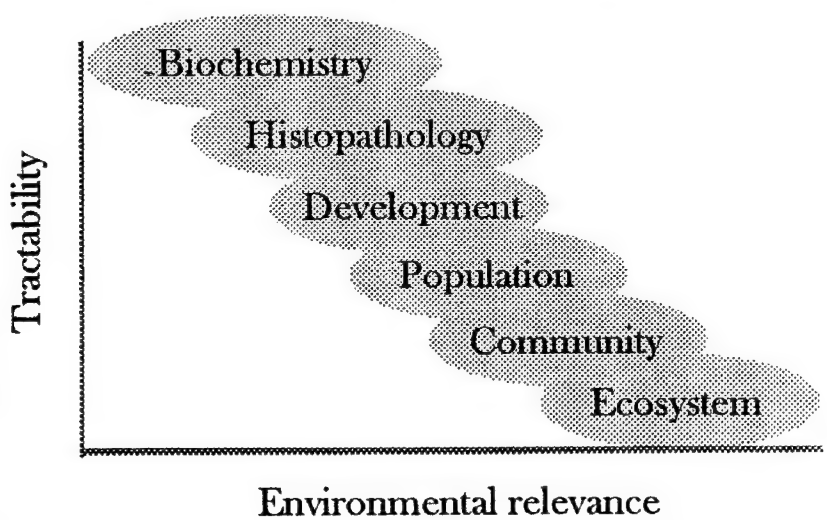
Acknowledgments

These pages describe research and software development by Applied Biomathematics with funding from the Electric Power Research Institute. Most of the work was done by Matthew Spencer, in collaboration with Nick Fisher and Wen Wang of the Marine Sciences Research Institute.

Abstract

To justify regulatory and mitigation decisions, toxicologists are often asked the "so what?" questions that demand predictions about the population or even ecosystem response to contamination. RAMAS Ecotoxicology is microcomputer software specifically created to assist toxicologists answer such questions by extrapolating effects on organisms observed in bioassays to their eventual population-level consequences. It provides a software shell from which users can construct their own models for projecting toxicity effects through the complex filters of demography, density dependence and ecological interactions in food chains. It allows various standard choices about low-dose response models (probit, etc.), which vital parameters are affected by the toxicant, the magnitudes and variabilities of these impacts, and species-specific life history descriptions. During the calculations, the software distinguishes between measurement error and stochastic variability. It forecasts the expected risks of population declines resulting from toxicity of the contaminant and provides estimates of the reliability of these expectations in the face of empirical uncertainty. This risk-analytic endpoint is a natural summary that integrates disparate impacts on biological functions over many organizational levels. Where applicable, the software automatically performs consistency tests to check that the input conforms to statistical assumptions and is dimensionally coherent. Parameterizations have already been prepared for several vertebrate and invertebrate species for use in assessments of soil or sediment contamination.

Impacts propagate through hierarchy



Incompleteness of bioassays

- Chooses endpoints arbitrarily
- Treats each insult separately
- Focuses on individuals
- Cannot answer 'So what?' questions

Despite the scientific difficulty, we need to increase environmental relevance of the assessments we make.

Why ecology *matters*

1) Cascade of impacts
2) Conflicting effects
3) Temporally lagged effects
4) Compensatory phenomena
5) Counterintuitive results
6) Indirect ecological effects

Cascade of impacts

For *sea turtles*, a 10% reduction in juvenile survival *might* well lead to extinction.

For *striped bass*, a 10% reduction in juvenile survival would *not* yield a detectable impact on the population.

Conflicting effects

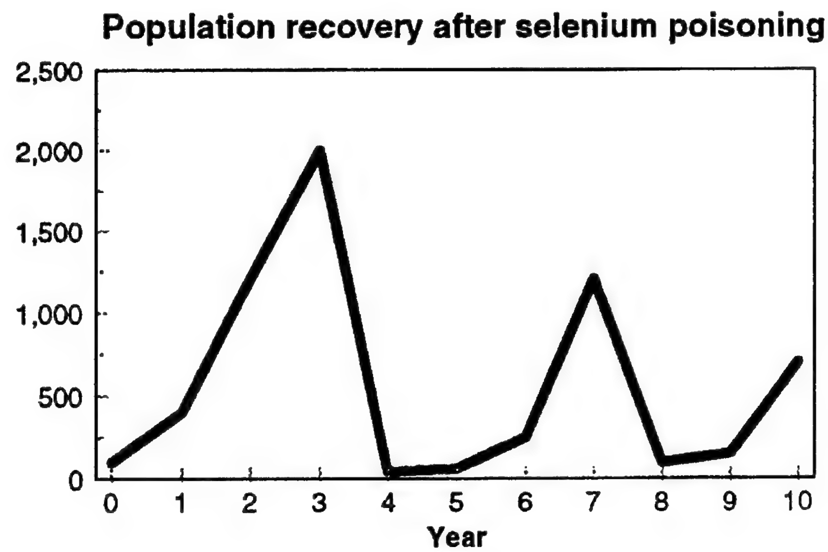
Suppose both

10% decline in survivorship

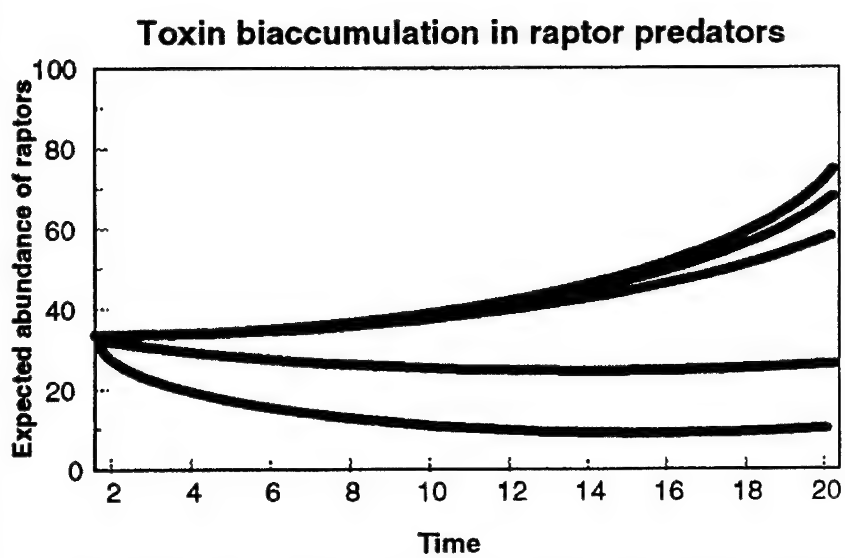
10% increase in reproduction

are observed. Is the overall effect on the population positive or negative?

Temporally lagged effects

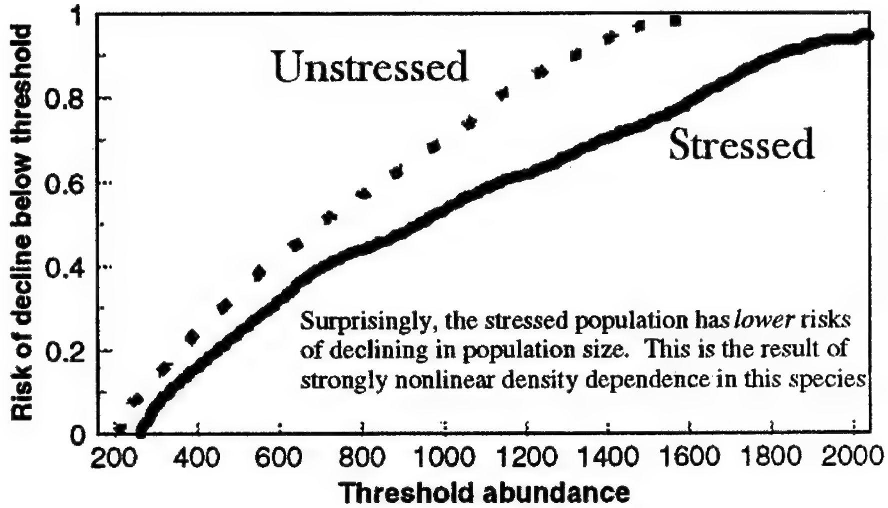


Compensatory phenomena

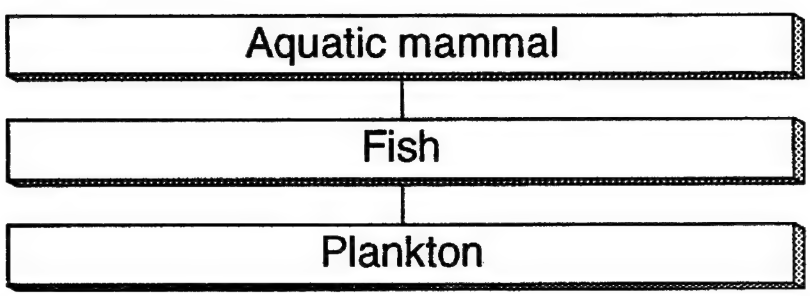


Countintuitive results

Toxicant impact on juvenile fish survival



Indirect ecological effects



- Reverberations in abundance
  (e.g., decline in mammals precipitates increase of fish and decline in plankton)

- Toxicant biomagnification
  (e.g., lipid-soluble toxicants become more concentrated up the food chain)

Talking past each other

Toxicant kinetics models

- assume population processes are slow
- neglect changes in populations

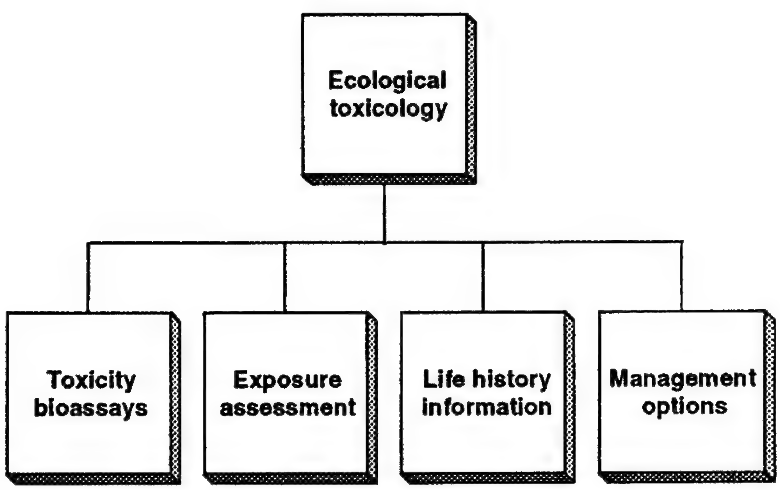
toxicant kinetics

population dynamics

Ecological models

- neglect changes in the concentration
- assume toxicant has equilibrated

A multidisciplinary problem



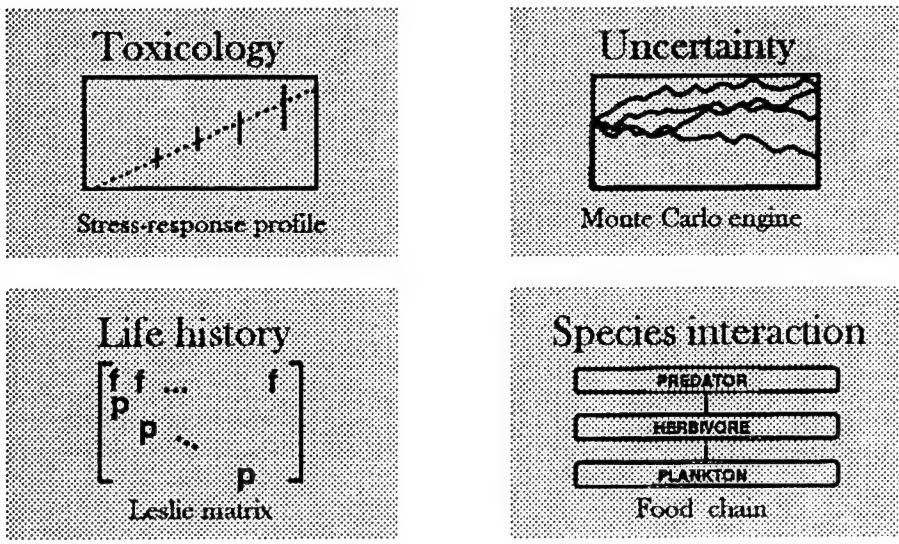
The RAMAS approach

- Offers wide choice to users
  Supports modeling choices listed below
- Checks that the model makes sense
  Does quality assurance for units, precision & assumptions
- Translates variability into risk
  Uses Monte Carlo methods to make the translation
- Accounts for uncertainty
  Propagates plus-minus intervals around parameters
- Uses the language of risk for output
  Expresses results in terms of risk of population decline, etc.

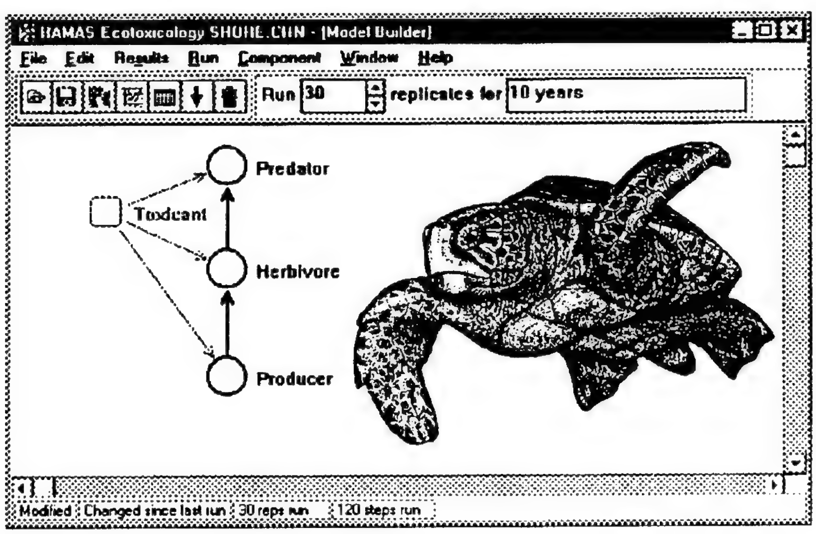
Credibility

- Over 700 institutional users worldwide
- Used in both research and academia
- Named "Distinguished Software"
- Favorably reviewed
  - *Quarterly Review of Biology*
  - *Bulletin of the Ecological Society of America*
  - *Natural Resource Modeling*
  - *Conservation Biology*
  - *Ecological Modelling*
- Numerous published applications

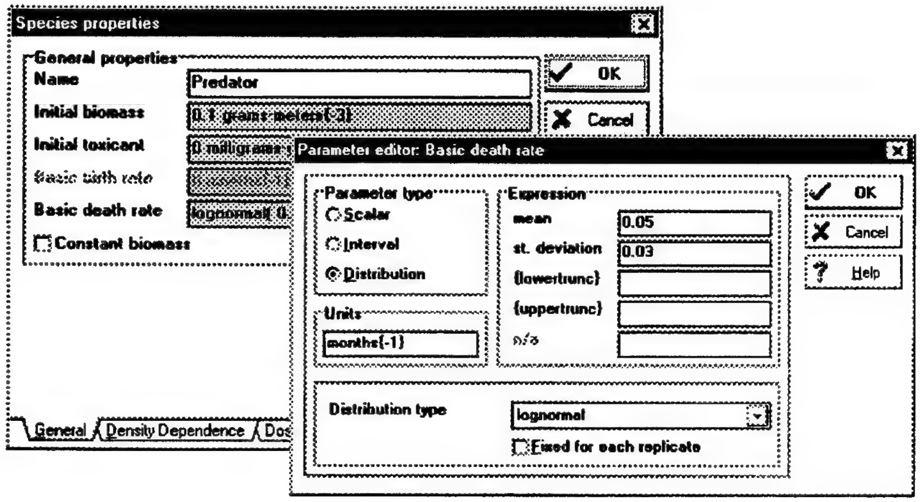
RAMAS Ecotoxicology



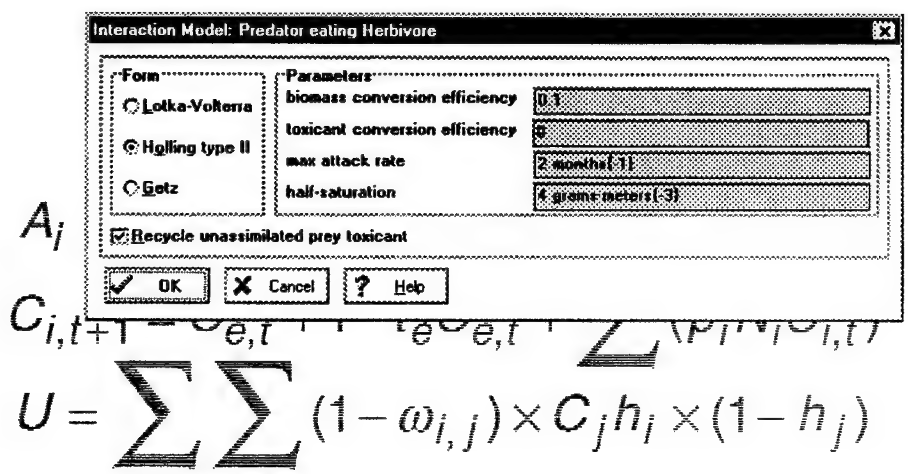
Create a model of population dynamics and toxicant kinetics using a simple Windows interface



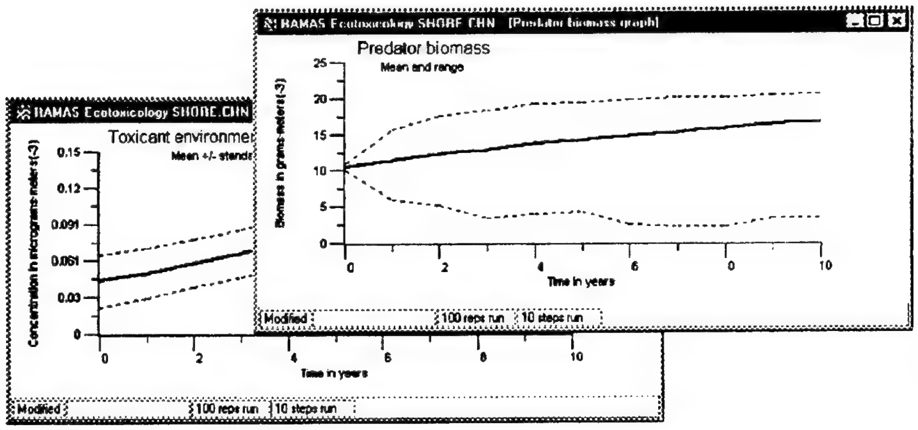
Specify parameters as scalars, intervals or probability distributions, in whatever units suit you



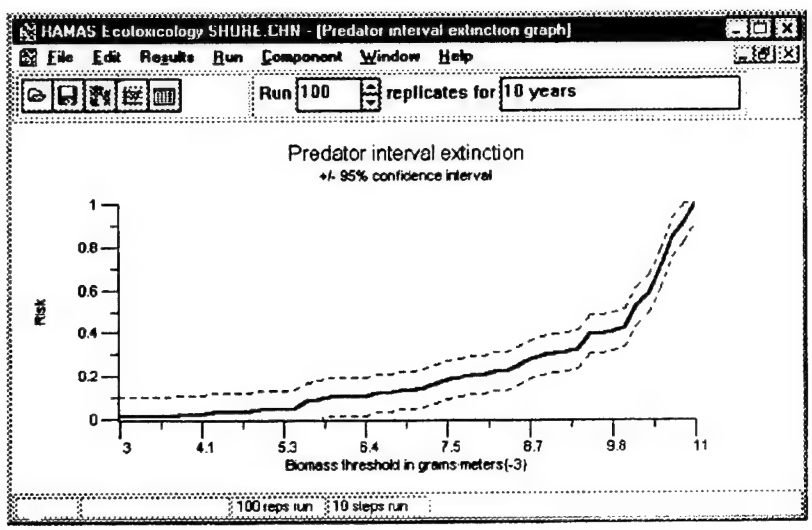
Choose the functional relationships between species, *without* writing equations



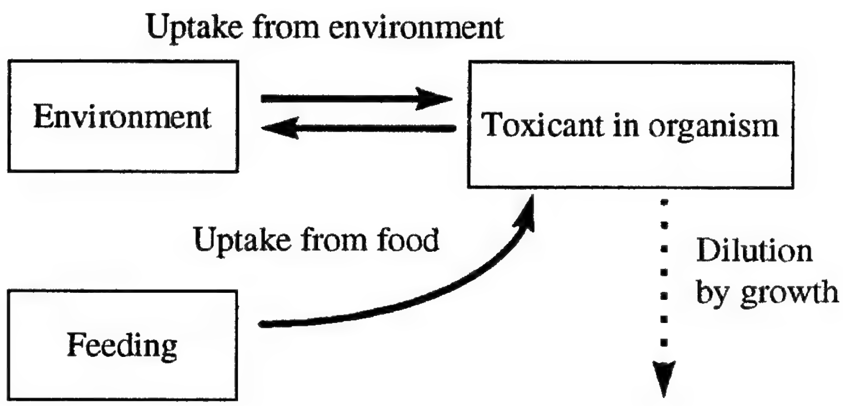
Do Monte Carlo simulations to take account of environmental variability and uncertainty in parameter values



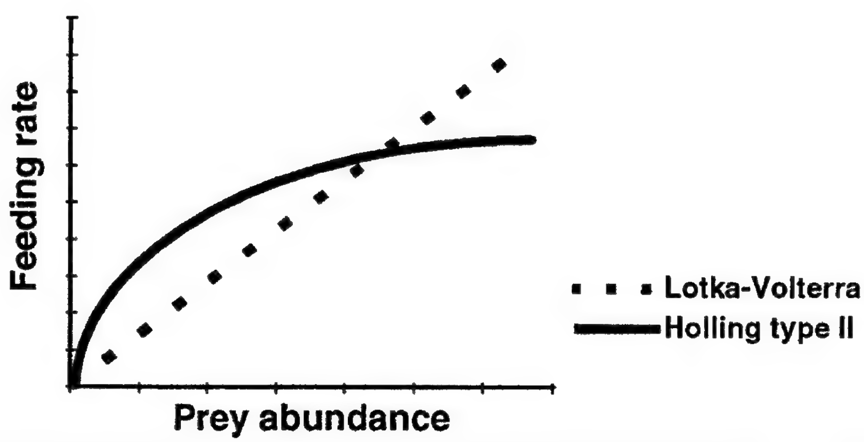
Calculate risks of events such as extinctions or population declines



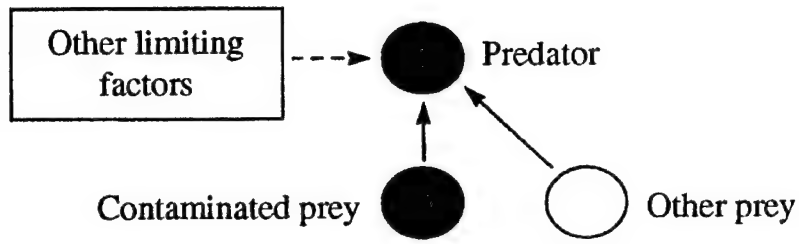
A simple model of bioaccumulation



Prey abundance affects feeding rate

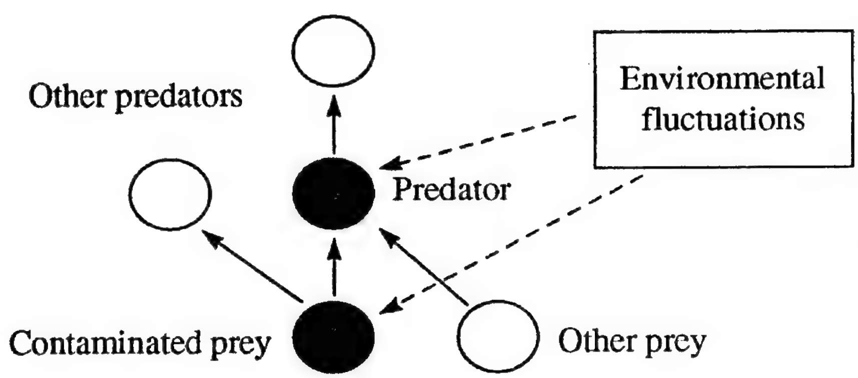


Feeding rate affects growth rate



- More food can support faster predator growth
- Alternative prey and other limiting factors can complicate
- Feeding on contaminated prey increases toxicant uptake

How do prey and predator interact?



Prey and predator won't be independent, but their relationship is complicated by their food web and the variable environment.

Conclusions

•Prey density affects toxicant uptake and predator growth rate.

•Density of predators and prey are unlikely to be independent.

•Predator-prey interactions therefore affect bioaccumulation.

•Modeling ecological interactions makes a big difference for predictions about toxicant concentrations.

Appendix G
You Don’t Need to Know a Lot of Ecology to Make a Comprehensive Ecological Risk Assessment

This appendix contains the presentation documents for “You Don’t Need to Know a Lot of Ecology to Make a Comprehensive Ecological Risk Assessment” by Scott Ferson - Applied Biomathematics.

You don't need a lot of data for a comprehensive risk analysis

S. Ferson
Applied Biomathematics
scott@ramas.com

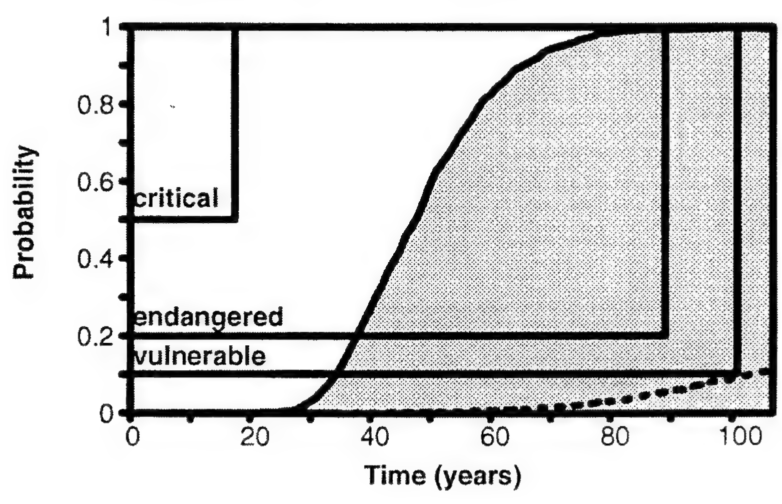
Why risk analysis isn't trusted

- Tool for obstructionists
  - to delay the project
  - to delay remediation
- Helps the other side
  - exposing subtle effects
  - an escape from a finding of toxicity
- ✓ Needs too much data
- ✓ Too expensive (requires consultants)
- ✓ Too complicated

Uncertainty analysis

Good uncertainty analysis can fix the last three problems.

Even though uncertainty is often large, and usually grows pretty fast, it may still permit clear decisions.



Basic considerations

- Underestimating uncertainty is lying
- Overestimating uncertainty is cowardice
- Giving priority to the public good is an ethical obligation

Three major problems

- Correlation and dependency ignored
- Input distributions unknown
- Mathematical structure questionable

Correlations and dependencies

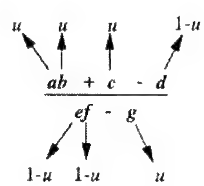
0) Independence assumptions

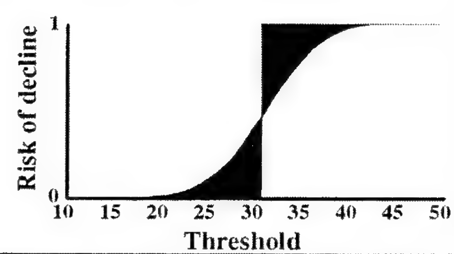
1) Dispersive Monte Carlo sampling

2) Dependency bounds analysis

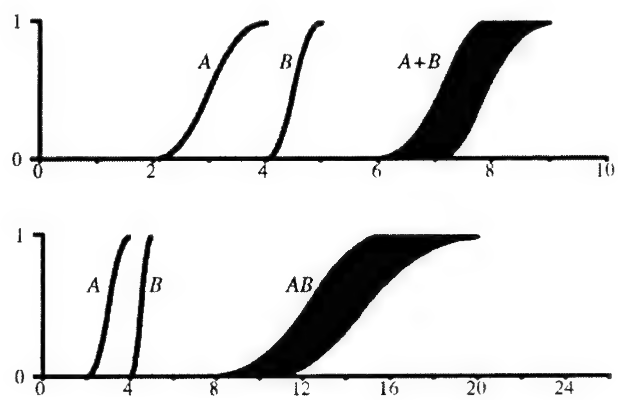
Dispersive Monte Carlo sampling

- Assume extreme correlations so result is as broad as possible
- Computationally cheaper than ordinary Monte Carlo methods





Dependency bounds analysis



Input distributions unknown

0) Default distributions

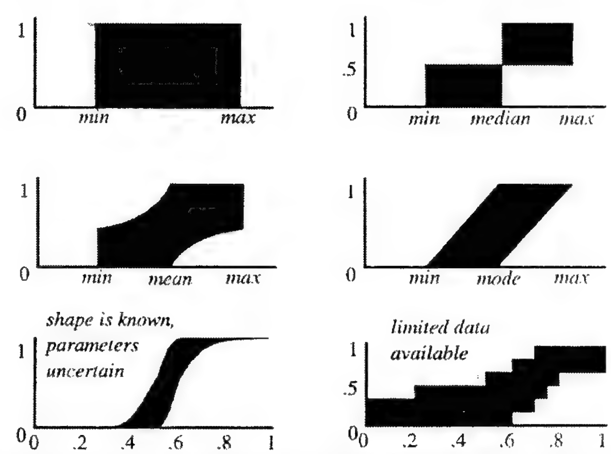
1) Maximum entropy

2) Probability bounds

Maximum entropy

- Generalizes Laplace's Principle of Insufficient Reason
  - {min, max} $\mapsto$ uniform
  - {mean, variance} $\mapsto$ normal
  - {min, max, mean} $\mapsto$ beta
  - {min = 0, mean} $\mapsto$ exponential
- Yields distribution with minimum bias and maximum uncertainty under the constraints

Probability bounds



Probability bounds

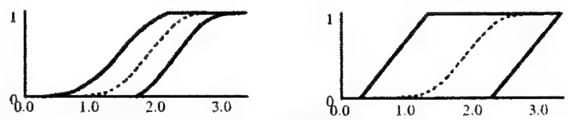
{min, max}
{min, max, mean}
{min, max, median}
{min, max, mean=median}
{min, max, mode}
{min, max, median=mean}
{mean, variance}
{shape=symmetric, mean, variance}
{shape=canonical, parameters}

P-bounds arithmetic

- +, −, ×, ÷, ^, min, max, exp, log, etc.
- **Quicker than Monte Carlo**
- **Guaranteed to bound answer**
- **Optimal solutions in most cases**

Sum of four p-bounds

A = {lognormal, mean=[.5,.6], variance=[.25,1]}
B = {min=0, max=.5, mode=.3}
C = {data = (.2, .5, .6, .7, .75, .8)
D = {shape = uniform, min=0, max=1}



Under independence Without independence

Mathematical structure

Given that validation is usually impossible when data are scarce...

0) "My model is correct"

1) Comprehensive battery of checks

2) Incorporate model uncertainty into the analysis

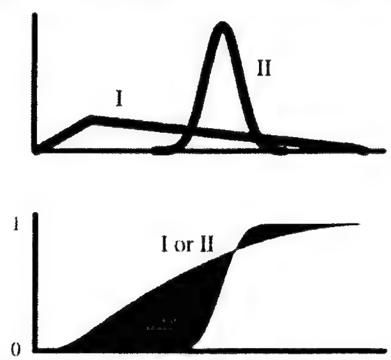
Battery of checks

- Generic checks
  - Dimensional and unit concordance
  - Feasibility of correlation structure
  - Consistence of independence assumptions
  - Single instantiations of repeated variables
- Checks against domain knowledge

  For instance, in ecological risk analysis...
  - Population sizes nonnegative
  - Trophic relations influence bioaccumulation
  - Food web structure constrained

P-bounds handles model uncertainty

- Reducible to parameter choice
- Reducible to distribution choice

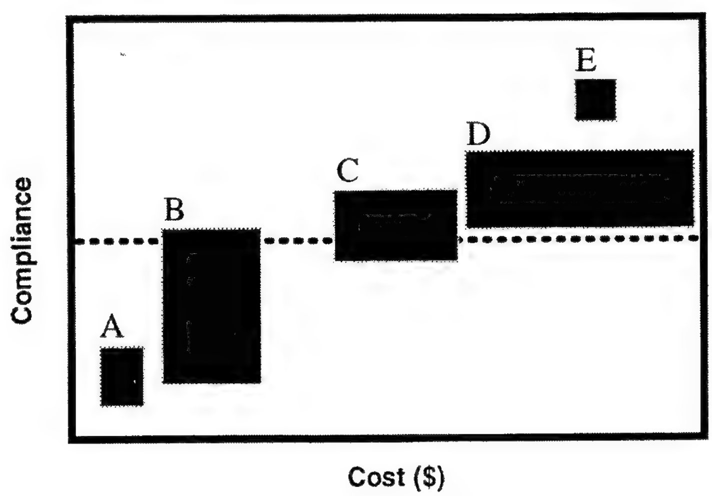


Advantages of p-bounds

- Much faster than second-order Monte Carlo
- Easy (graphical) parameterization
- Handles uncertainty about
  - parameter values
  - distribution shapes
  - dependence and correlation among variables
  - even the form of the model itself
- Faithful to frequentist interpretation

Strategies

Uncertainty about success and cost



Appendix H
Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

This appendix contains the presentation documents for "Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model" by Bill Mills - Tetra Tech, Inc.

Risk Analysis of Potentially Contaminated Sites Using EPA's MMSOILS Multimedia Model

Prepared For:
U.S. Army Engineer Waterways
Experiment Station Risk Assessment
Modeling Workshop

New Orleans, Louisiana

May 14-15 1998

Prepared by:

William B. Mills

Christine Lew

Katherine Hancock

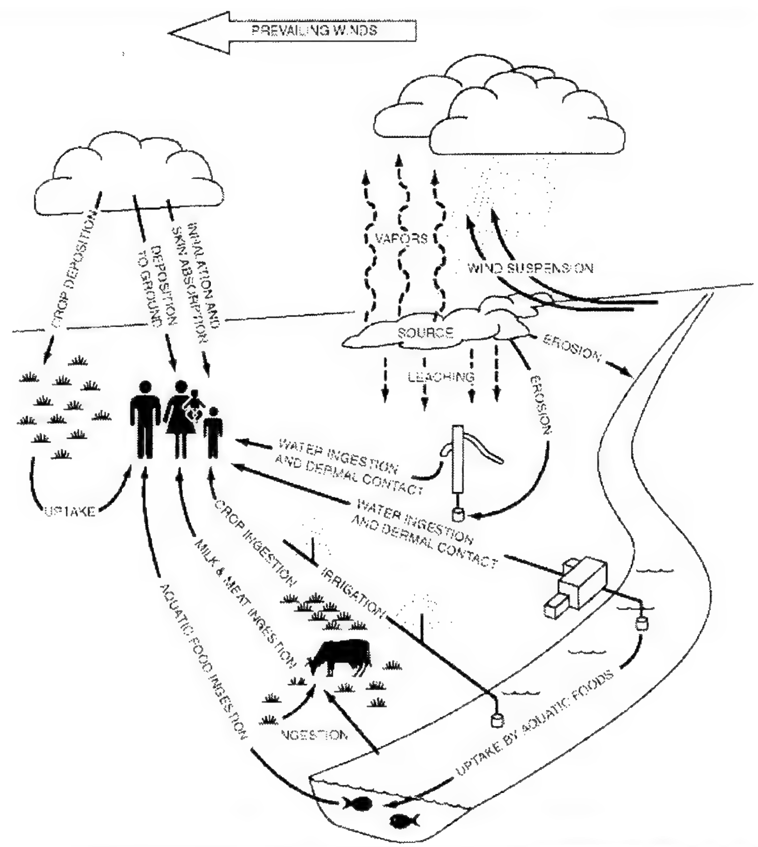
Tetra Tech, Inc.

Lafayette, CA

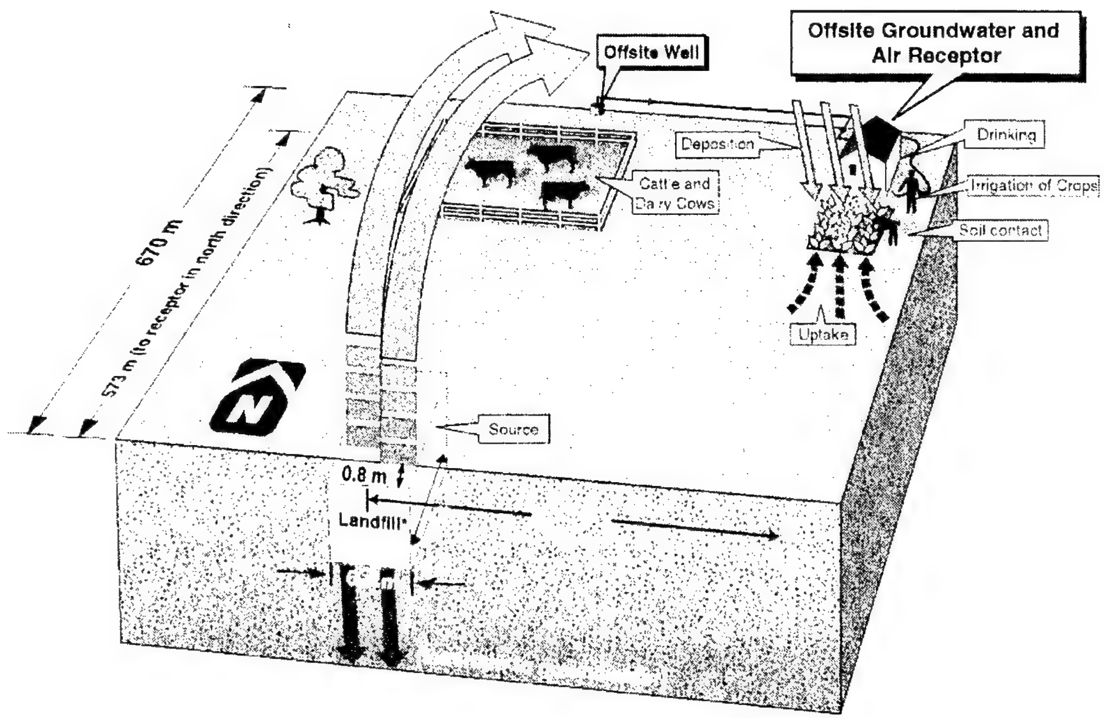
Purpose of Presentation

- Provide an Introduction to MMSOILS: Its uses and limitations
- Demonstrate how MMSOILS used in one EPA Program (HWIR) to provide an initial assessment of many sites

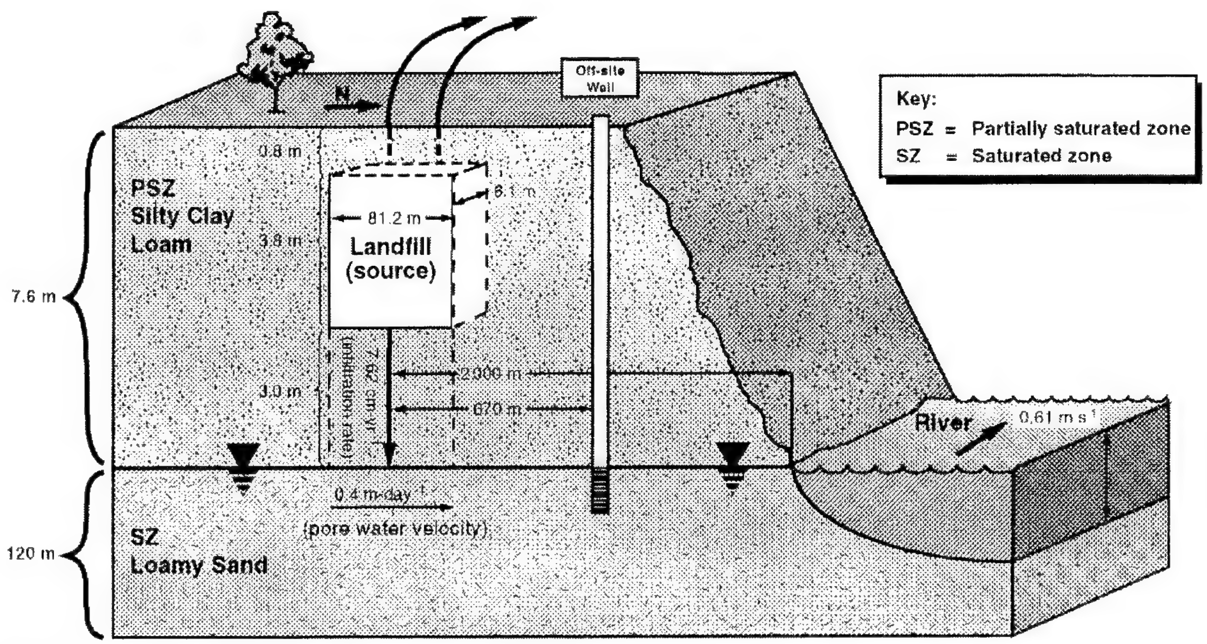
Coupling Between Contaminant Source and Receptor



Multimedia Environmental Setting Locations of Receptors



Multimedia Environmental Setting Source, Soil Strata, and Locations of Well and River.



Note: drawing not to scale.

Selected Features of MMSOILS Multimedia Models

- Contaminant Transformation and Fate Processes
- Intermedia Contaminant Fluxes
- Exposure Pathways
- Human Health Risk Measures
- Media-specific Transport

Application to EPA's HWIR

- HWIR:
  - *Hazardous Waste Identification Rule*
- Purpose of HWIR:
  - *To evaluate if certain low-risk wastes can be disposed of as* ***nonhazardous***
- "Exit" Rule:
  - *At what concentrations can specific chemicals "exit" hazardous waste disposal requirements <u>and</u> be protective of human health and the environment?*

Scope of HWIR

- Nationwide:
  - *Disposal could occur at WMUs throughout the United States*
- Chemicals:
  - *Approximately 400 Chemicals*
- WMUs:
  - *Landfills*
  - *Impoundments*
  - *Waste piles*

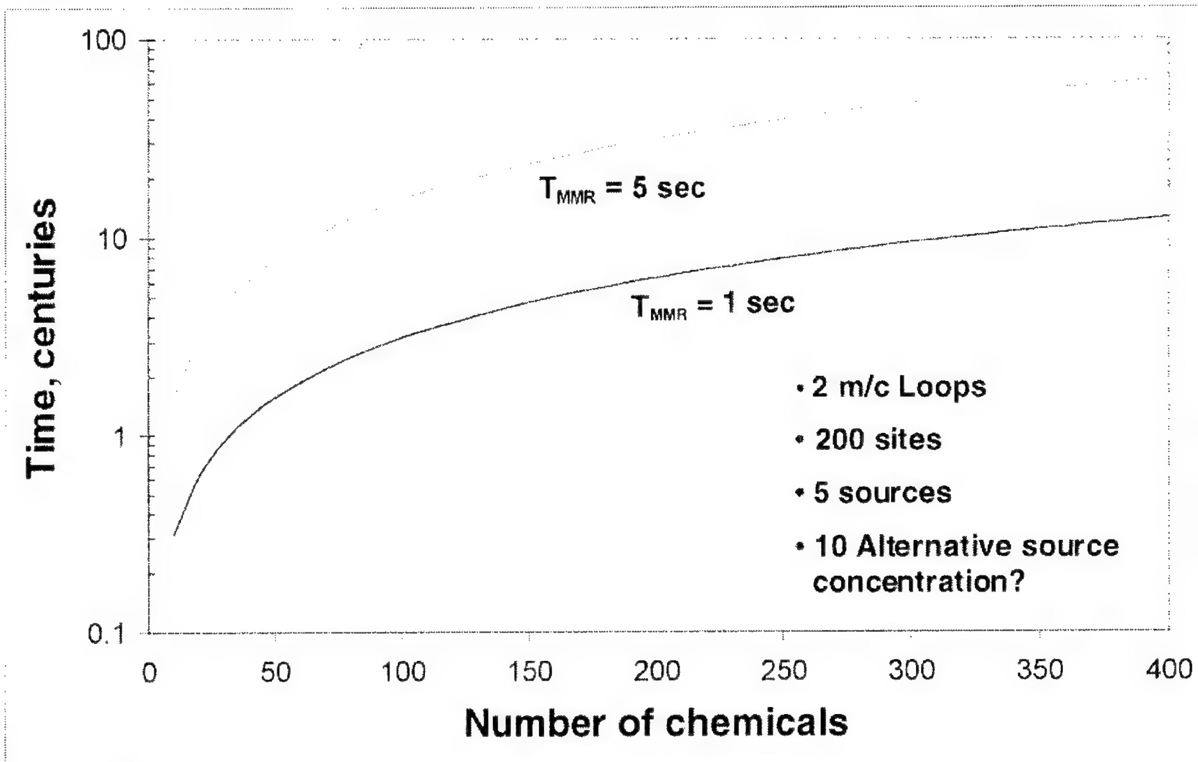
EPA's Approach

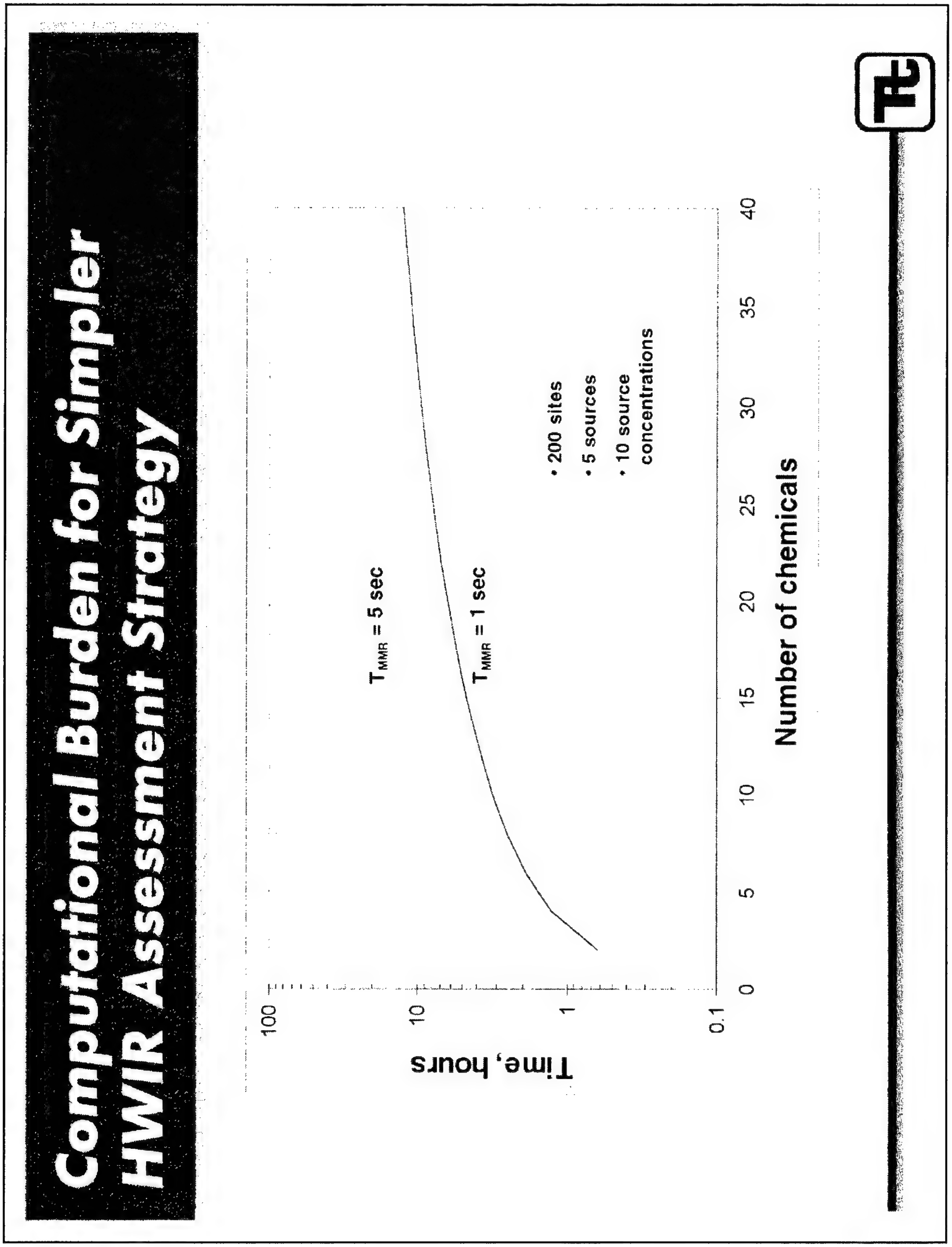
- Multimedia/Multi-pathway
- Risk Based:
  - Human health and Ecological
- Site Based
  - Create plausible sites (hundreds per source type) throughout US
  - Assume each chemical could be disposed at each site

Factors that Influence Computational Effort to Implement HWIR

- Hundreds of sites
- 5-6 source types
- 400+ chemicals
- Range of source concentrations
- Monte Carlo loops (2)

Computational Burden for One Alternative HWIR Assessment Strategy





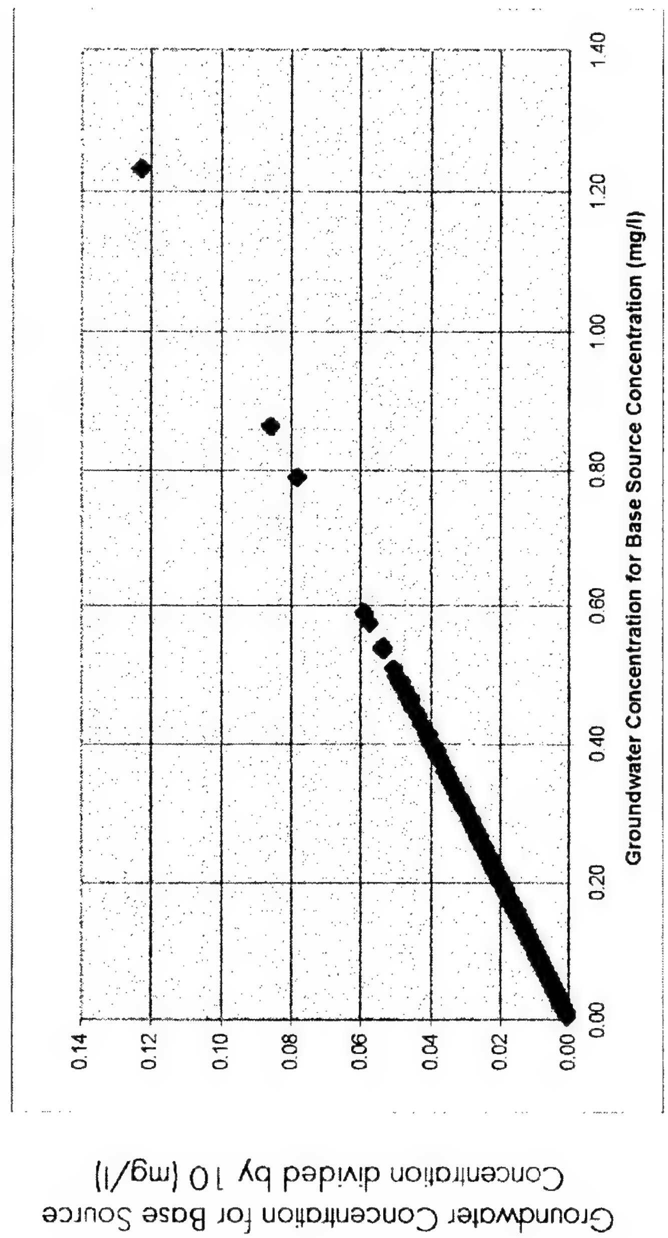
Computational Burden for Simpler HWIR Assessment Strategy
Time, hours
100
10
1
0.1
0
5
10
15
20
25
30
35
40
Number of chemicals
T_{MMR} = 5 sec
T_{MMR} = 1 sec
• 200 sites
• 5 sources
• 10 source concentrations

Investigation of Other Means of Reducing Computational Burdens

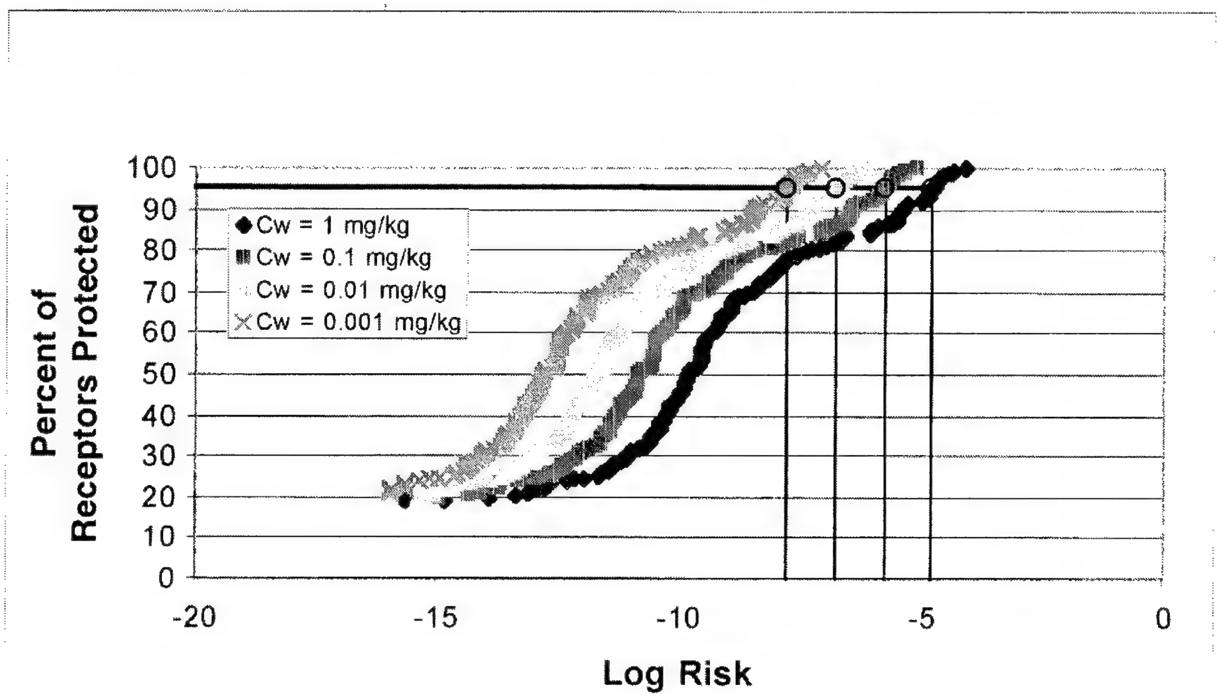
- ❑ *Making use of linearity*
- ❑ *Grouping of chemicals*
- ❑ *Risky Vs nonrisky sites*
- ❑ *Minimizing number of random variables*

How to Control Computational Burden

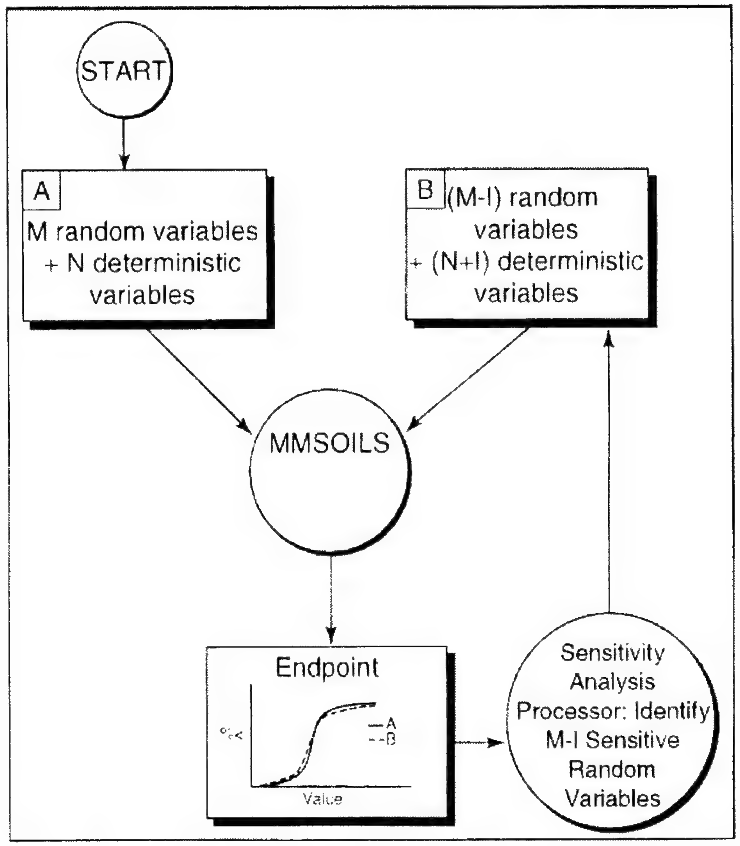
- Examine *linearity* in source concentration (HWIR exit concentration)

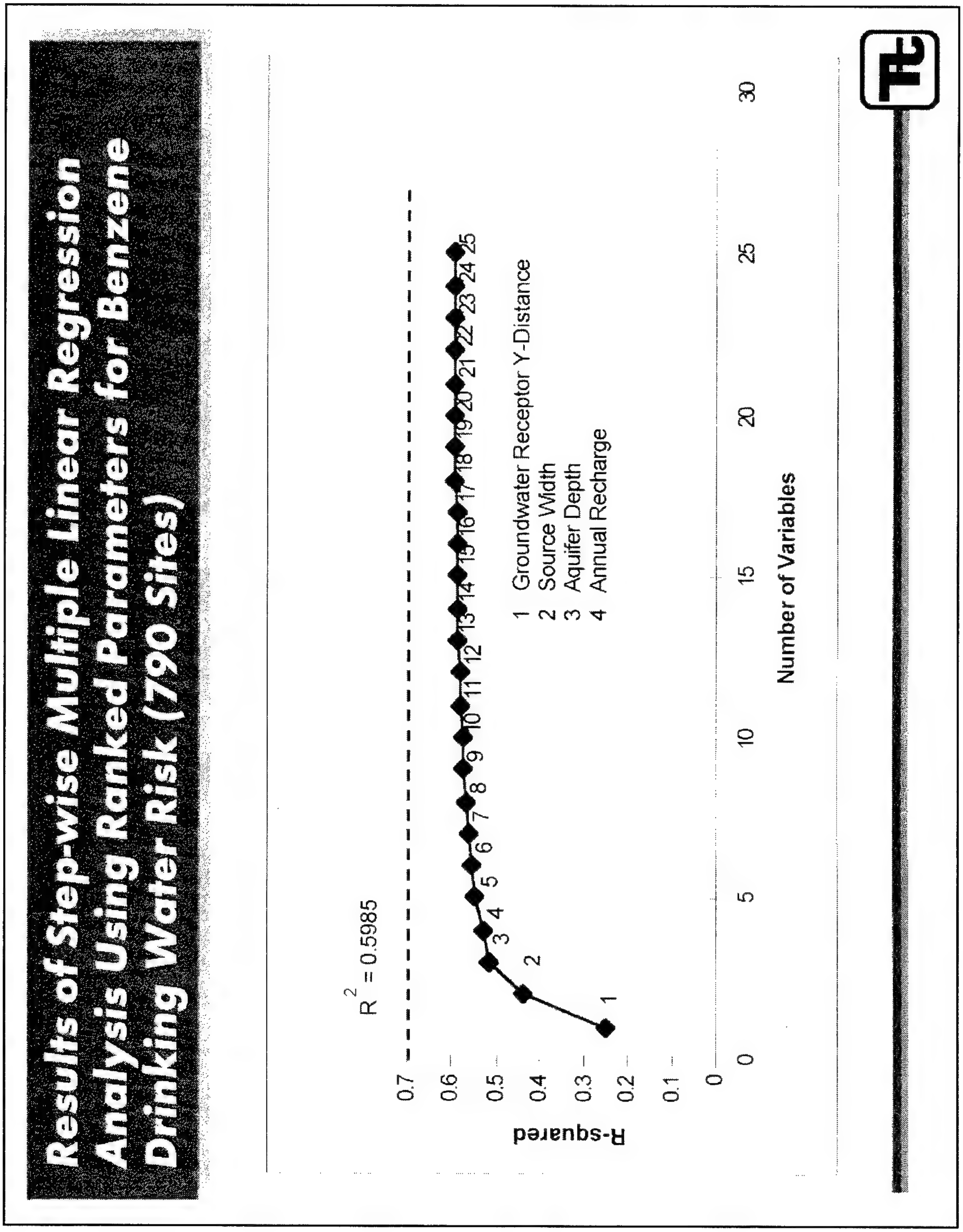


Percent of Receptors Protected versus Different Risk Levels for Various Cw's

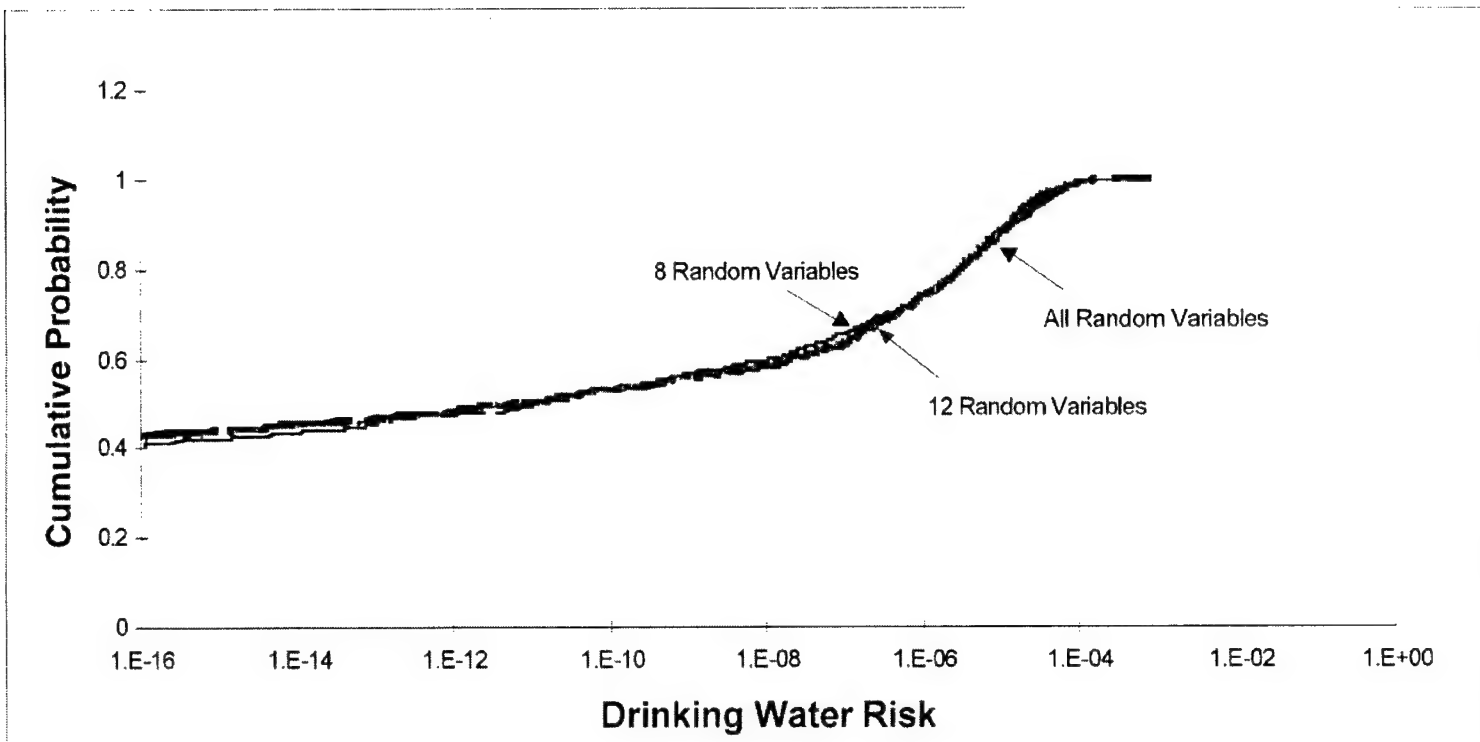


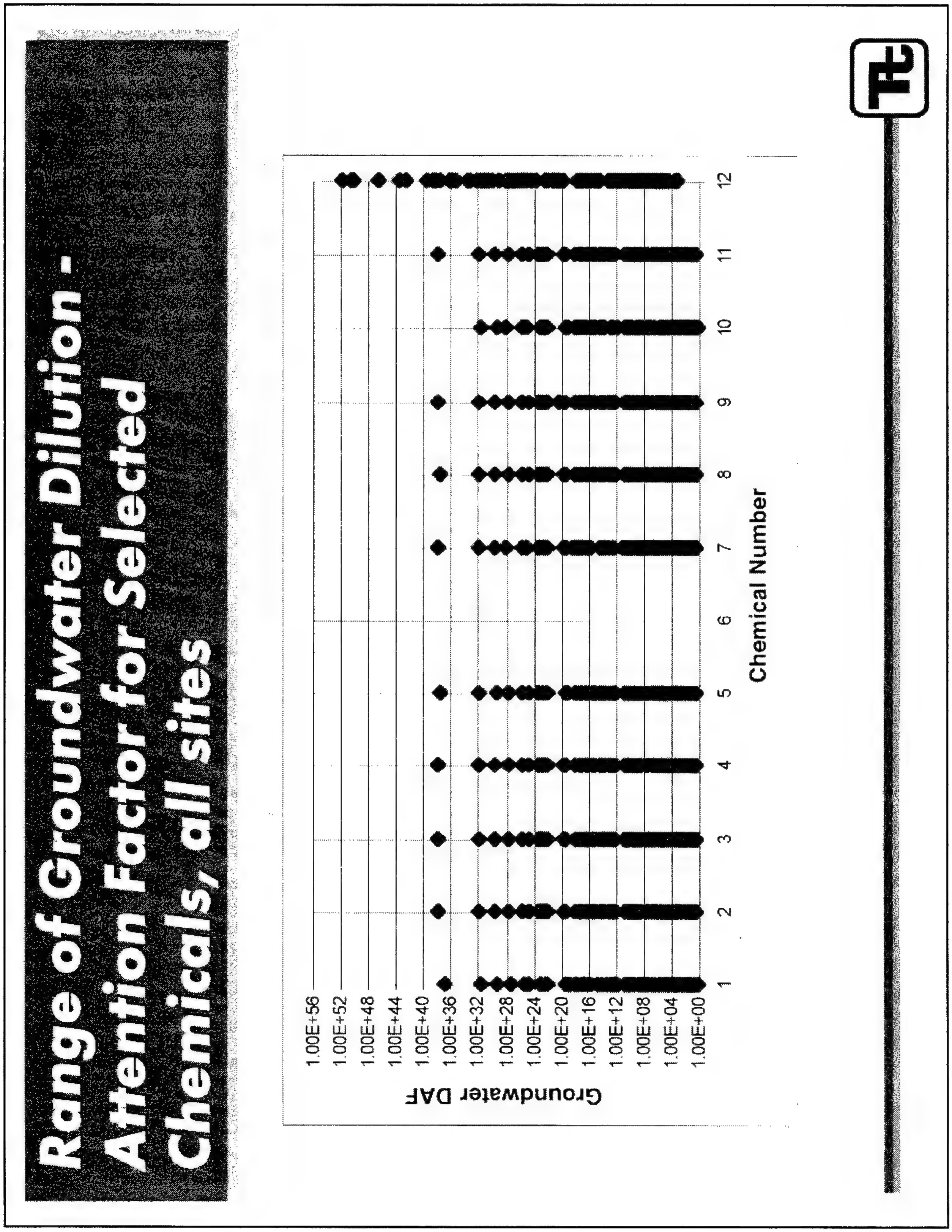
Uncertainty Analysis
What Makes a Difference?

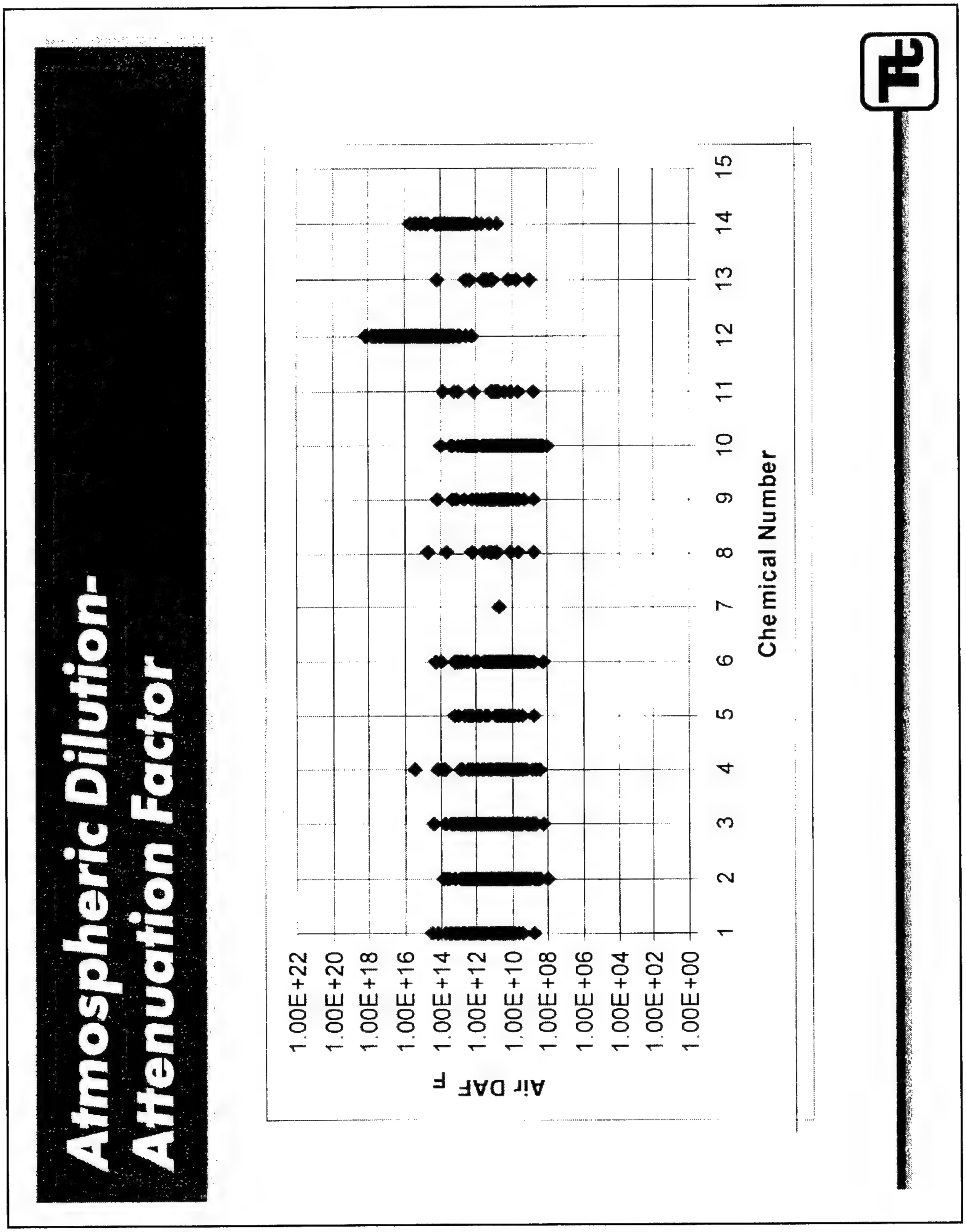



Results of Step-wise Multiple Linear Regression Analysis Using Ranked Parameters for Benzene Drinking Water Risk (790 Sites)
R-squared
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
$R^2 = 0.5985$
0
5
10
15
20
25
30
Number of Variables
1 Groundwater Receptor Y-Distance
2 Source Width
3 Aquifer Depth
4 Annual Recharge

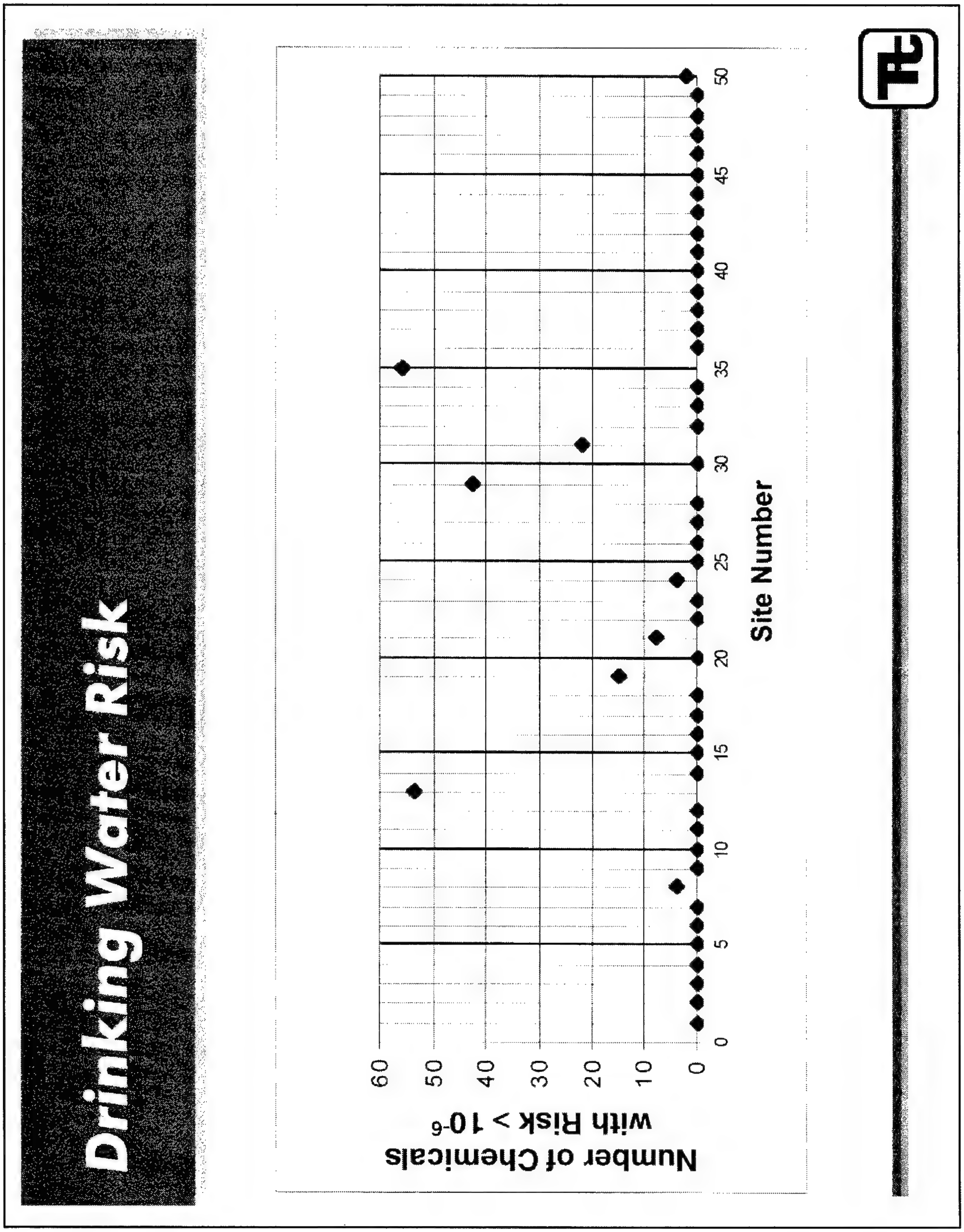
CDF of Benzene Drinking Water Risk for 8, 12, and All Random Variables

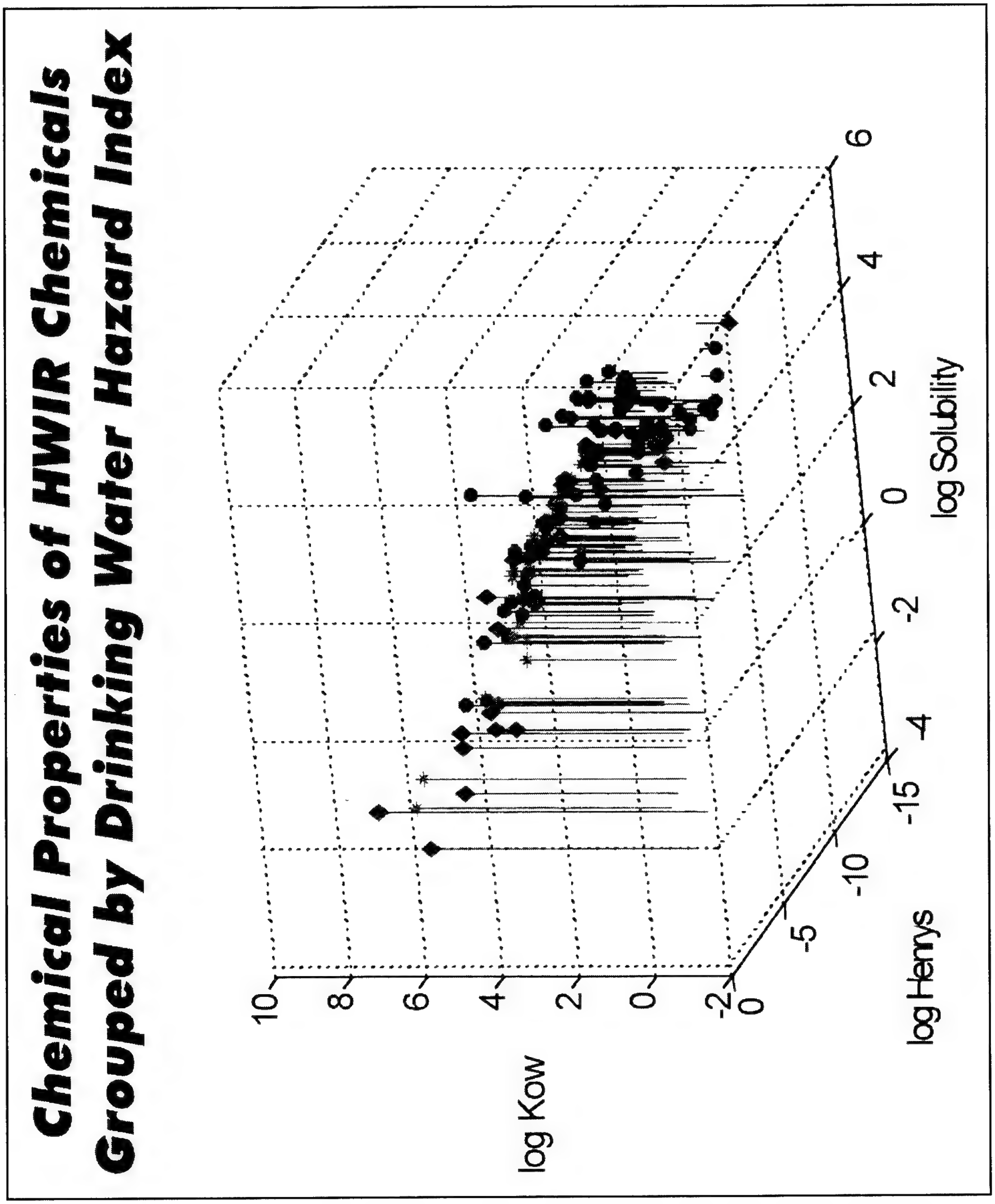



Range of Groundwater Dilution - Attention Factor for Selected Chemicals, all sites
Groundwater DAF
1.00E+56
1.00E+52
1.00E+48
1.00E+44
1.00E+40
1.00E+36
1.00E+32
1.00E+28
1.00E+24
1.00E+20
1.00E+16
1.00E+12
1.00E+08
1.00E+04
1.00E+00
1
2
3
4
5
6
7
8
9
10
11
12
Chemical Number



Atmospheric Dilution-
Attenuation Factor
Air DAF F
1.00E+22
1.00E+20
1.00E+18
1.00E+16
1.00E+14
1.00E+12
1.00E+10
1.00E+08
1.00E+06
1.00E+04
1.00E+02
1.00E+00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Chemical Number


Drinking Water Risk
Number of Chemicals with Risk > 10^{-6}
0
10
20
30
40
50
60
0
5
10
15
20
25
30
35
40
45
50
Site Number


Chemical Properties of HWIR Chemicals
Grouped by Drinking Water Hazard Index
log Kow
10
8
6
4
2
0
-2
0
-5
-10
-15
logHenrys
-4
-2
0
2
4
6
log Solubility

Matrix of Drinking Water Risk by Chemical and Site

Site \ Chemical	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
2	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
3	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
4	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
5	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
6	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
7	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
8	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
9	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
10	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
11	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
12	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
13	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
14	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
15	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
16	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
17	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
18	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
19	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
20	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
21	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
22	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
23	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
24	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
25	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
26	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
27	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
28	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
29	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
30	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
31	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
32	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	
33	NA		NA	NA	NA	NA		NA			NA	NA		NA						NA								NA	NA	NA		NA	

Key

R < 10

10 <= R <= 10

R > 10

NA Chemical does not have carcinogenic risk

Conclusion

- *Screening-level multimedia/multipath model applied preliminarily to HWIR program*
- *Purpose is to help streamline the expected large computational effort*
- *Means to accomplish this are being investigated: linearity; site grouping; chemical grouping*

Appendix I
Metapopulation Models and Ecological Risk Analysis: A Habitat-Based Approach to Biodiversity

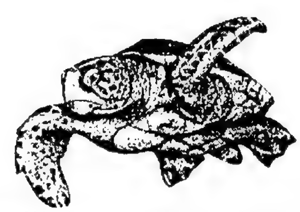
This appendix contains the presentation documents for "Metapopulation Models and Ecological Risk Analysis: A Habit-Based Approach to Biodiversity" by H. Resit Akcakaya - Applied Biomathematics. Complete information for references cited in this appendix was provided in handouts at the time of the workshop.

METAPOPULATION MODELS AND ECOLOGICAL RISK ANALYSIS: A HABITAT-BASED APPROACH TO BIODIVERSITY CONSERVATION

H. Reşit Akçakaya

Applied Biomathematics
100 North Country Road
Setauket, New York 11733

Risk Assessment Modeling Workshop
New Orleans, 14-15 May 1998



resit@ramas.com

Importance of metapopulation dynamics

Modelers ingore spatial structure at their own risk

Spatially explicit metapopulation models

Practical compromise between complexity and applicability

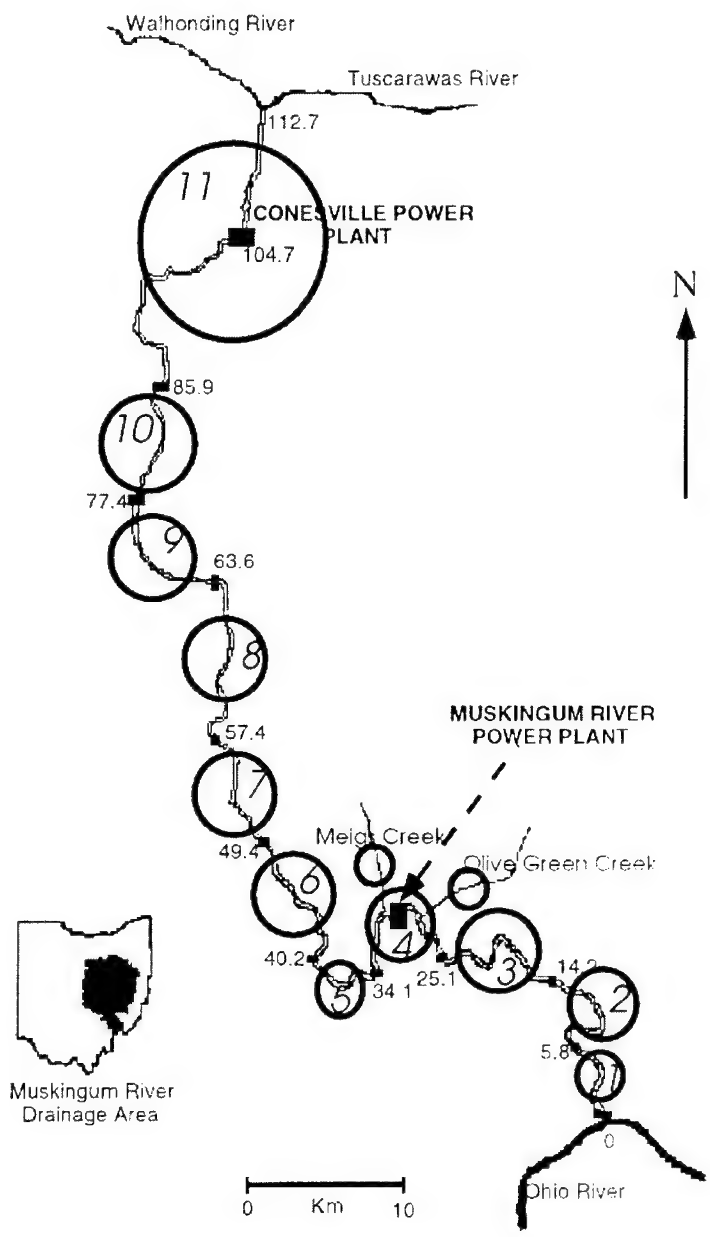
Future directions

Incorporating habitat relationships

Multi-species approaches

Metapopulations in trophic chains

SPATIAL STRUCTURE OF THE GOLDEN REDHORSE METAPOPULATION IN THE MUSKINGUM RIVER, OH



resit@ramas.com

WHY ARE METAPOPULATIONS IMPORTANT?

Assessing impacts at the metapopulation level

- Impacts on single populations
- Fragmentation:
  - change in distribution of habitat patches
  - decrease in total area
  - smaller populations
  - increased edge effects
- Decreased dispersal / Increased isolation

Evaluating management options at the metapopulation level

- Reintroduction/translocation
- Reserve design
- Habitat corridors

Complicated dynamics

- Many models of single populations don't make a metapopulation model
- Extinction risk is sensitive to additional factors at the metapopulation level

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WHAT MAKES METAPOPULATION DYNAMICS DIFFERENT?

Factors affecting population dynamics

- Demography: survival, fecundity, growth
- Age or stage structure
- Density dependence
- Environmental fluctuations, catastrophes
- Demographic stochasticity

Additional factors affecting metapopulation dynamics

- Number of populations
- Geographic configuration
- Spatial correlation
- Migration patterns

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METAPOPULATION MODELS

Model	Advantages	Disadvantages
Occupancy	Analytical solution Generalizations	Unrealistic assumptions Difficult parameters Few or infinitely many patches
Spatially explicit	Flexible and realistic Few implicit assumptions	Numerical errors possible Data intensive Difficult to add genetics
Individual-based	Very flexible and realistic	Easy to make numerical and/or logical errors Very data-intensive Sensitive to behavioral assumptions

resit@ramas.com APPLIED BIOMATHEMATICS

FUTURE DIRECTIONS IN METAPOPULATION MODELING

Incorporating habitat into metapopulation models

1. Identifying species-habitat relationship
2. Determining habitat patches based on distribution of suitable habitat
3. Estimating population-level and metapopulation-level parameters based on habitat-related variables:

Metapopulation model parameters:	Based on habitat variables:
initial population abundance, $N_i(0)$	total habitat suitability
carrying capacity of the patch, K_i	average habitat suitability
stage-specific survival, S_k	edge length (perimeter)
stage-specific fecundity, F_k	patch area (or core area)
population growth rate, R_{max}	habitat variables (vegetation, elevation, flow, temperature)
dispersal among patches, M_{ij}	inter-patch distances
correlation among patches, ρ_{ij}	

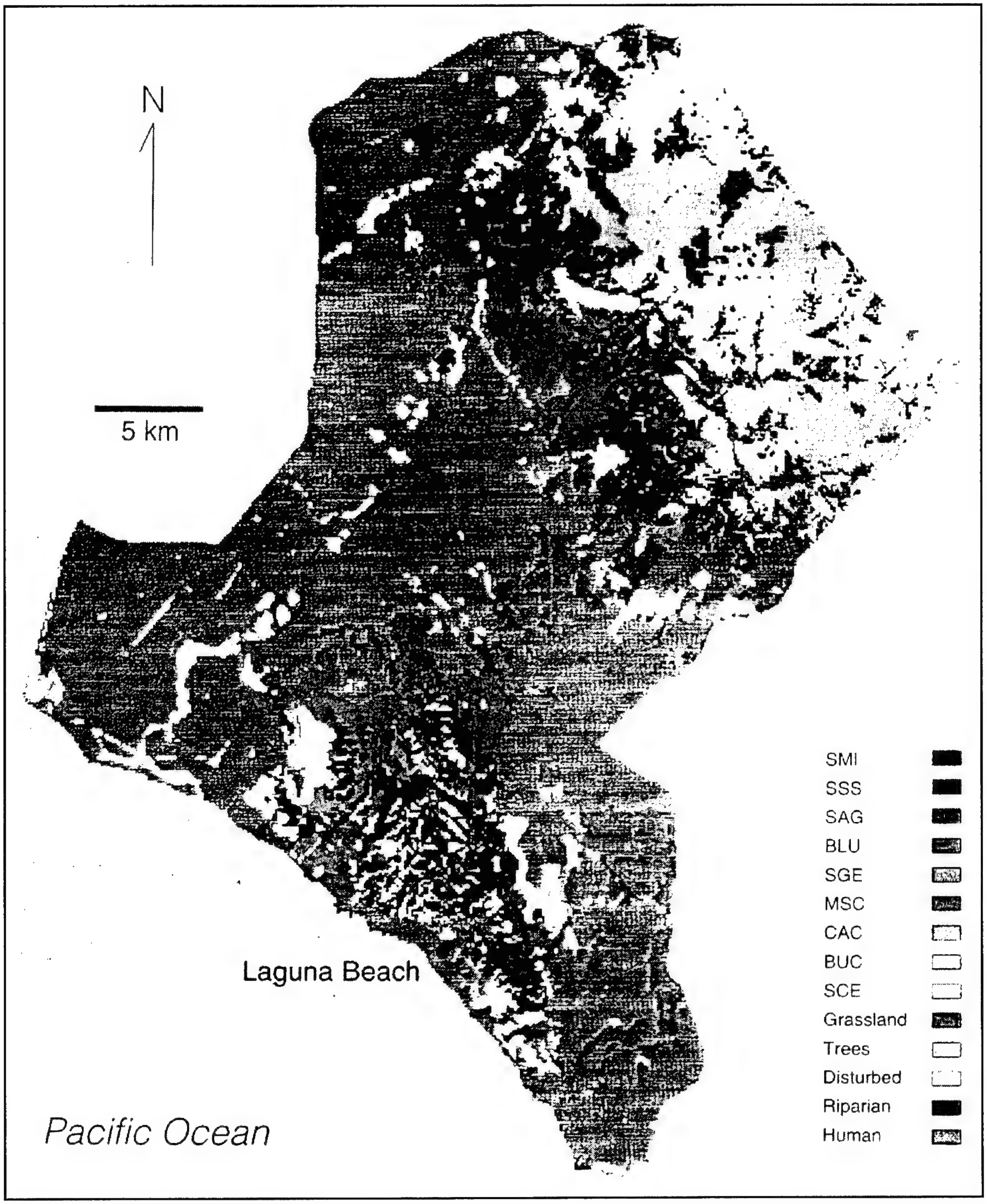
resit@ramas.com

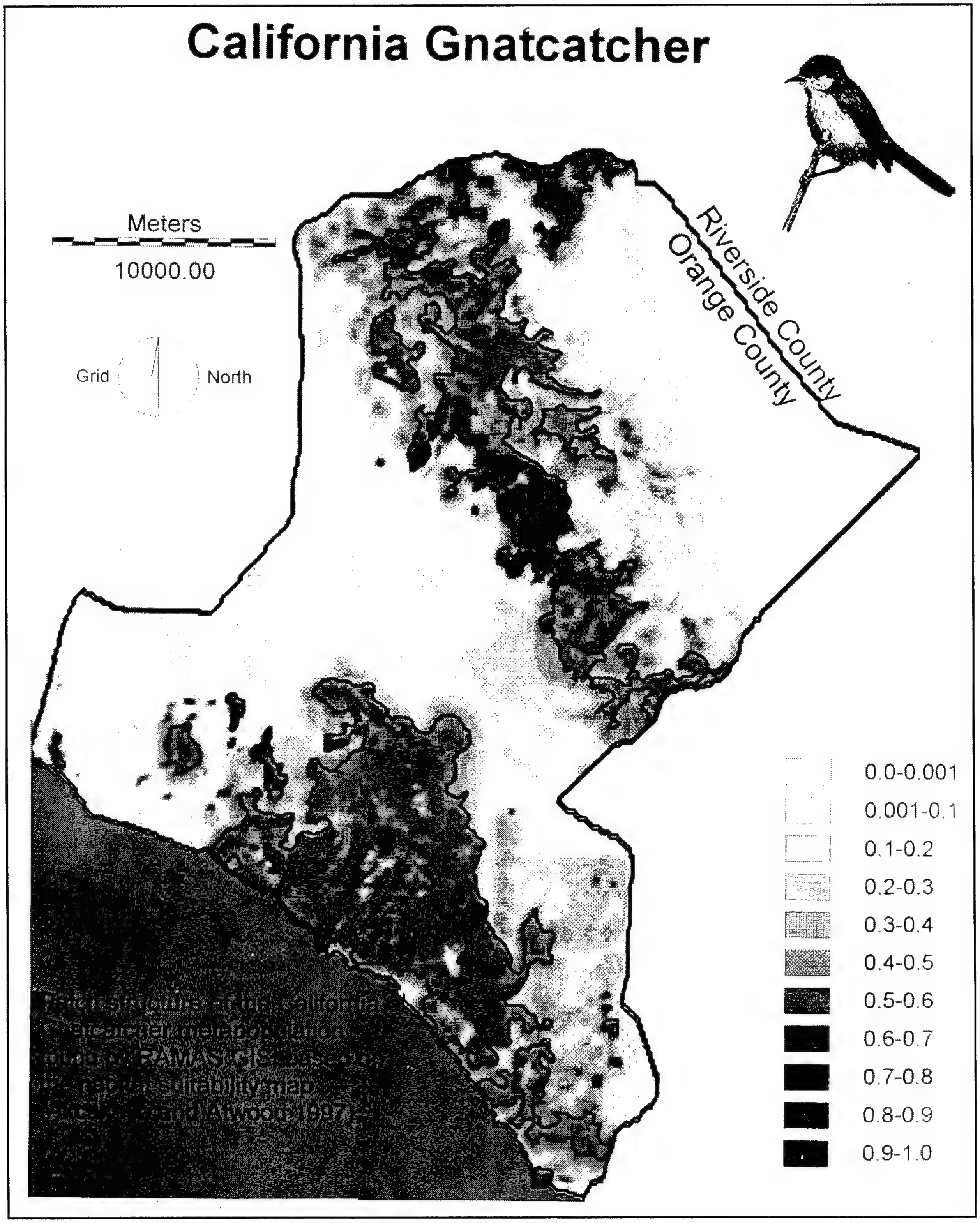
A Habitat-based Metapopulation Model of the California Gnatcatcher in Orange County, CA

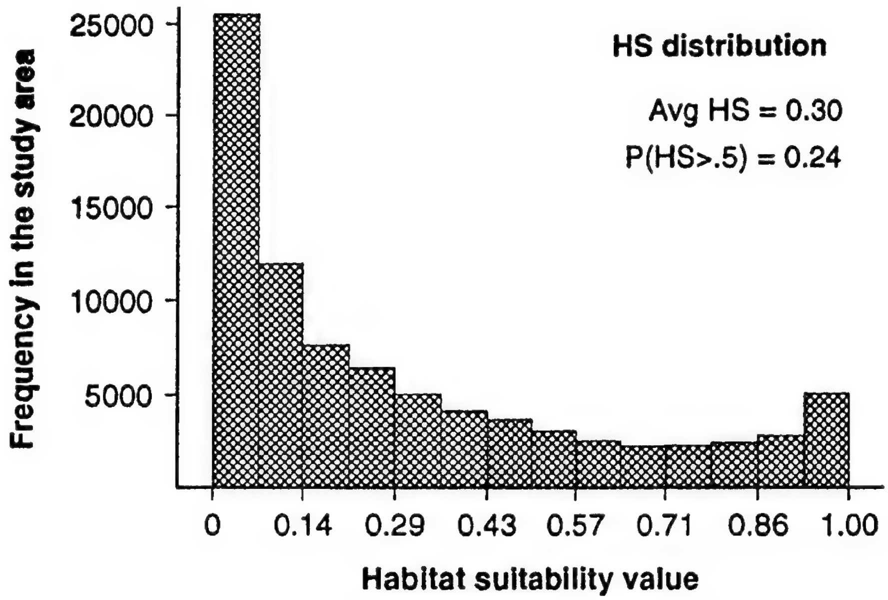
H. Reşit Akçakaya
Applied Biomathematics, Setauket, NY

Jonathan Atwood
Manomet Observatory, Manomet, MA

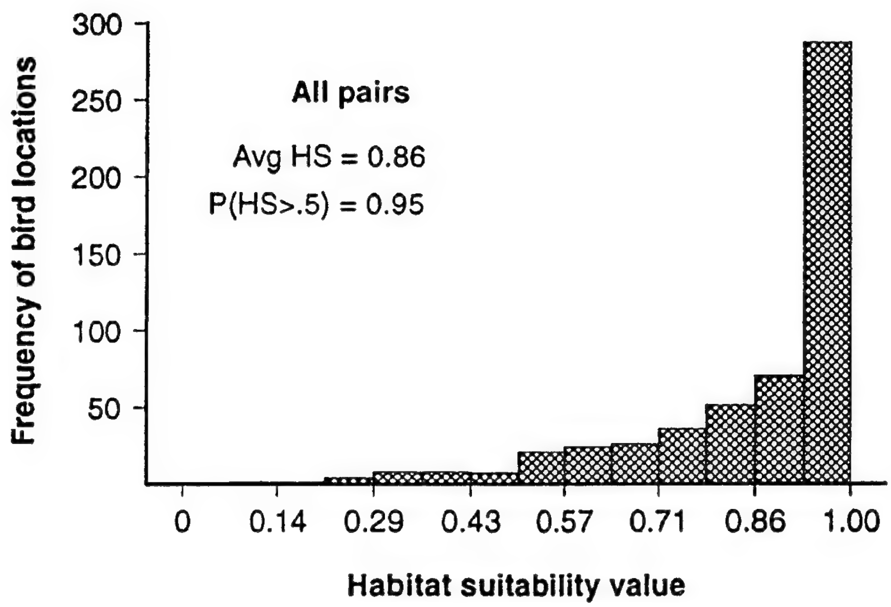
Conservation Biology **11**:422-434 (April 1997)


N
5 km
Laguna Beach
Pacific Ocean
SMI
SSS
SAG
BLU
SGE
MSC
CAC
BUC
SCE
Grassland
Trees
Disturbed
Riparian
Human

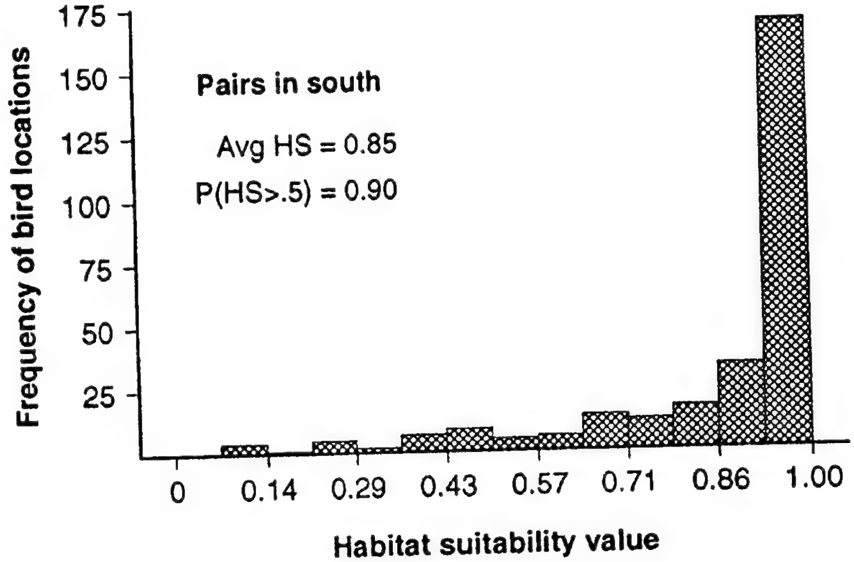

California Gnatcatcher
Meters
10000.00
Grid
North
Riverside County
Orange County
0.0-0.001
0.001-0.1
0.1-0.2
0.2-0.3
0.3-0.4
0.4-0.5
0.5-0.6
0.6-0.7
0.7-0.8
0.8-0.9
0.9-1.0



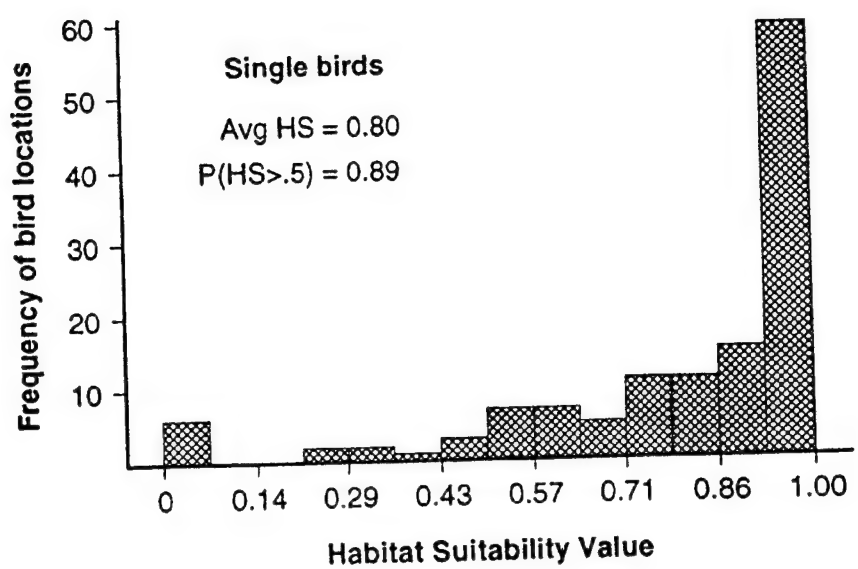
Habitat suitability (HS) values for California Gnatcatchers in the study area, calculated for each of 85,333 1-ha cells.



Goodness of fit: Habitat suitability (HS) values of locations where California Gnatcatcher pairs were observed in the study area.



Validation 1 (North - to - South):
Habitat suitability (HS) values of locations of pairs in the south.
Predicted with the HS function using the locations of pairs in the north.



Validation 2 (Pair - to - Single):
Habitat suitability (HS) values of locations of single birds.
Predicted with the HS function using the locations of pairs.

California Gnatcatcher

	Juvenile	Adult
Juvenile	0.5376*	0.8899
Adult	0.3441	0.4975

*post-reproductive census: juvenile fecundity = $P_{JB} \cdot M$
= proportion of last year's juveniles that are breeders this year, multiplied with number of fledglings per breeder.

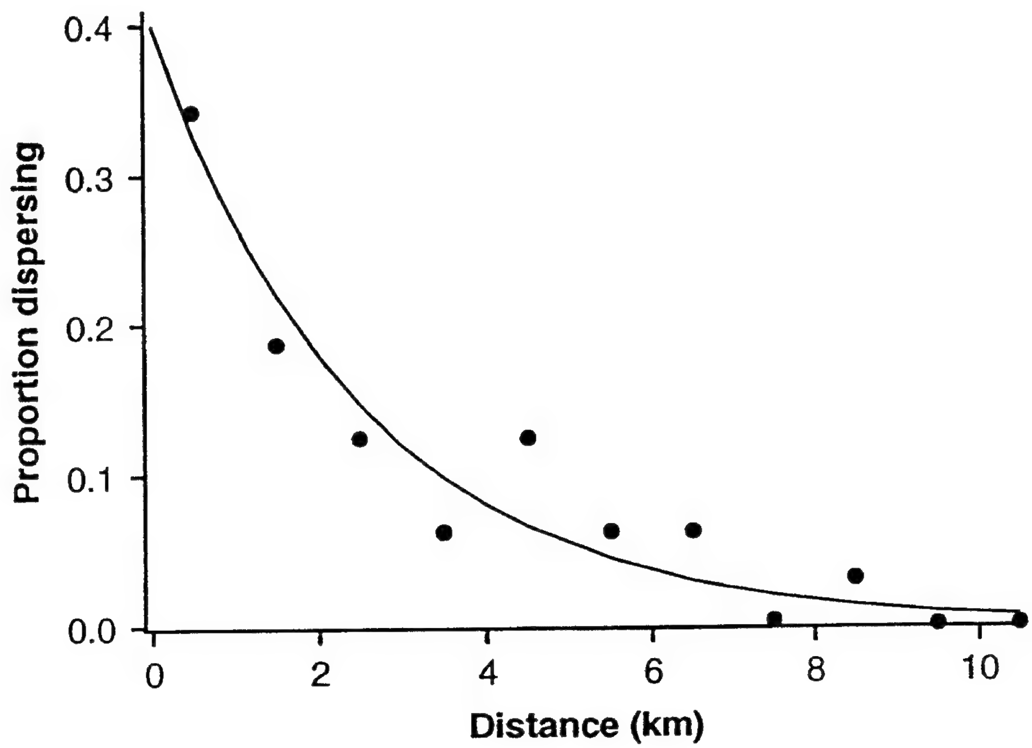
Spotted Owl

	Juvenile	Subadult	Adult
Juvenile	0.0258	0.0779	0.1288
Subadult	0.884	0	0
Adult	0	0.884	0.884

*pre-reproductive census: fecundity = $M \cdot S_0$
= number of fledglings per breeder, multiplied with the survival rate from fledgling to (1-year-old) juvenile

Metapopulation dynamics: Dispersal (migration)

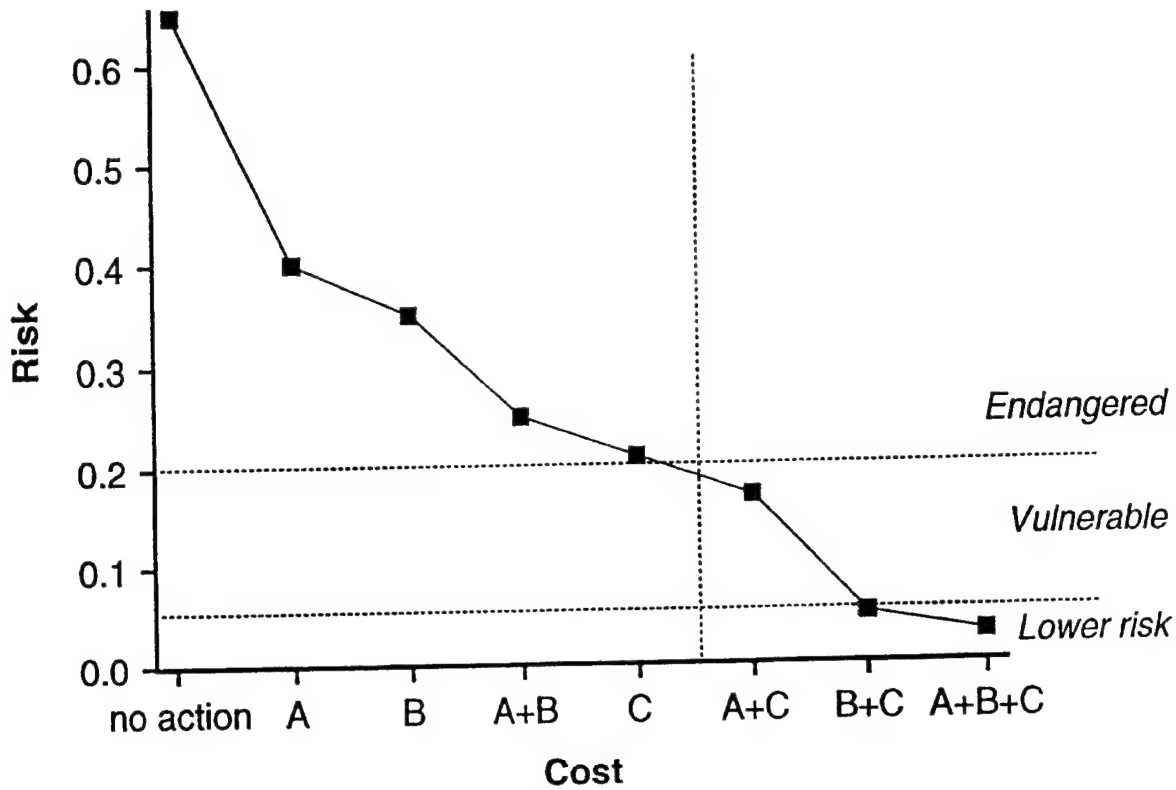
- Biology of the species
- Landscape characteristics
- Distance among patches
- Direction (e.g., downstream vs. upstream)
- Age or stage (e.g., only juveniles disperse)
- Density (e.g., higher emigration when crowded)
- Variability (demographic stochasticity)



Proportion of dispersing juveniles as a function of distance (in km). Data from Atwood et al. (1995b). The curve is the function $y=0.4 \cdot \exp(-x/2.5)$.

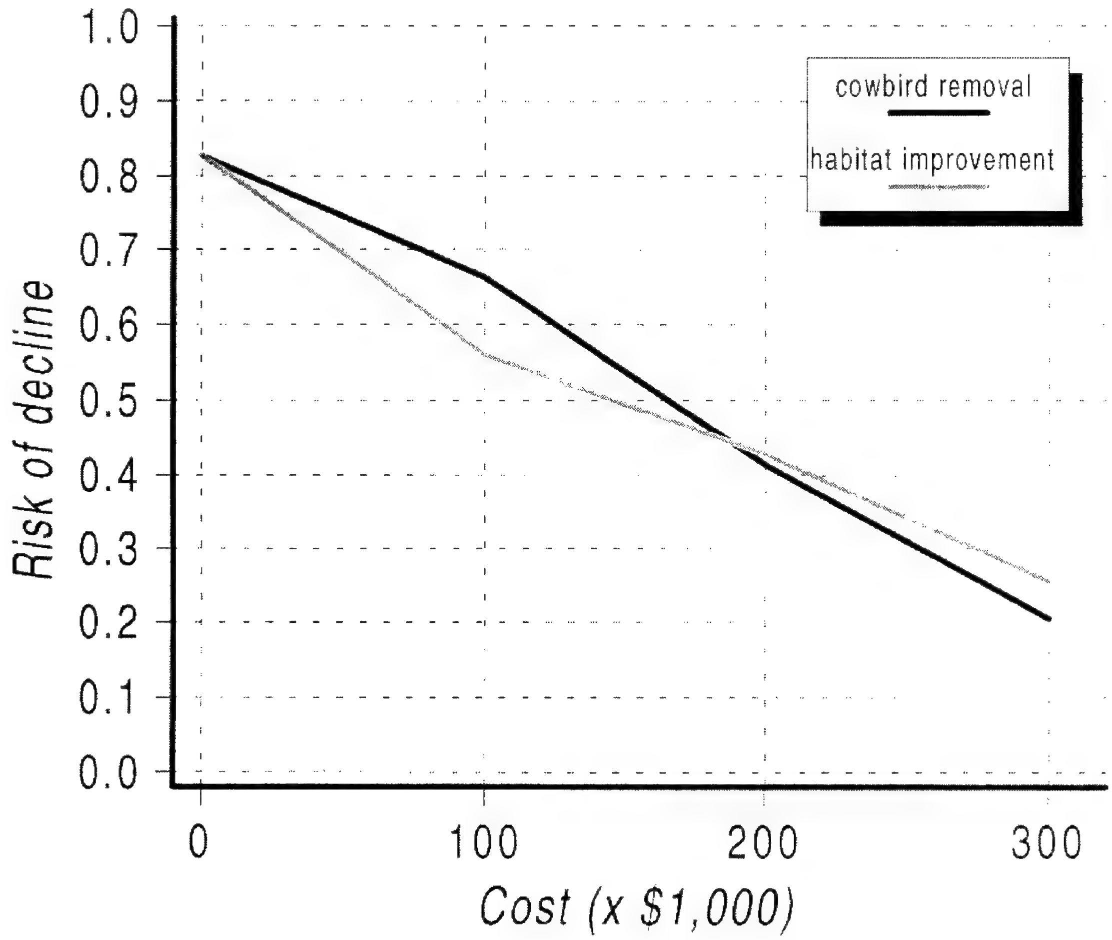
Cost-Benefit Analysis

Akcakaya, Burgman, Ginzburg (1997)



Risk of extinction of a hypothetical metapopulation with no management ("no action" option), and under 7 options (which involve improving the habitat in one, two or all three of the three habitat patches, A, B,and C).
The options are in order of increasing cost from left to right.

METAPOPULATION RISK ANALYSIS AS A MANAGEMENT TOOL



Using the model to evaluate management options: Hypothetical comparison of two management options (removing cowbirds that parasitize gnatcatcher nests and improving habitat) in terms of their cost and the reduction in the risk of decline.

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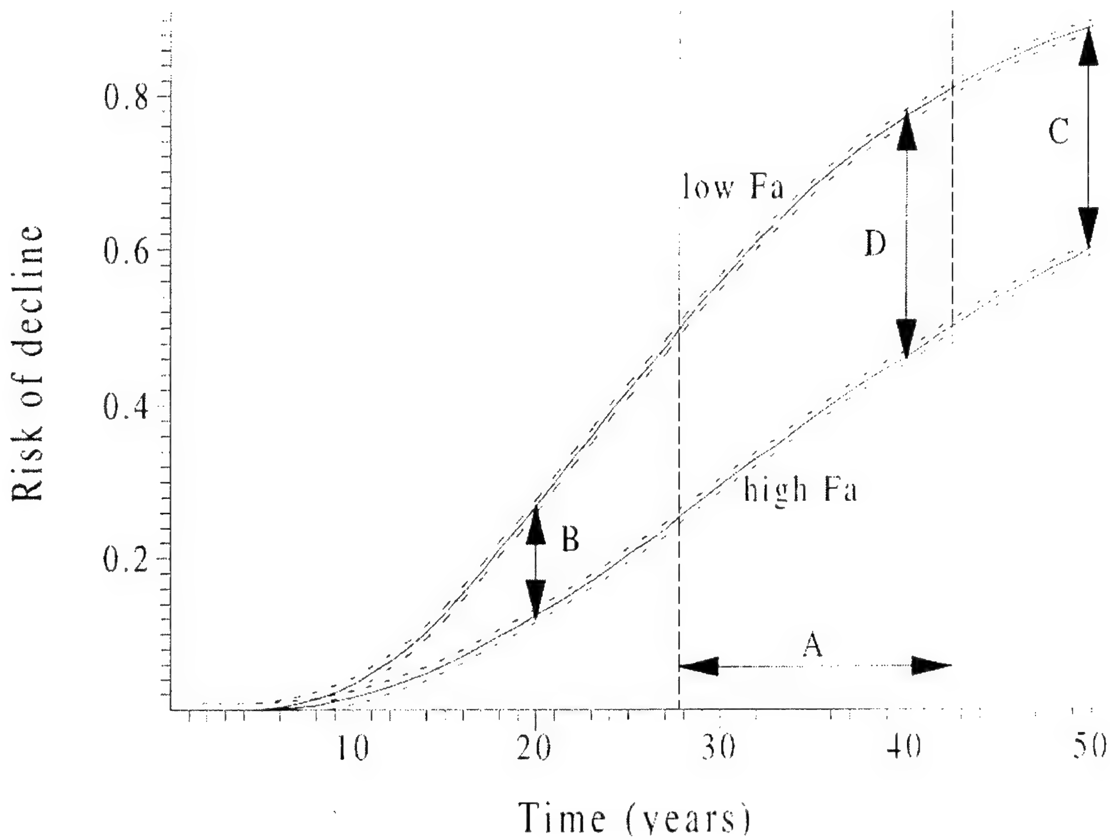
UNCERTAINTY IN RISK ANALYSIS: GNATCATCHER VIABILITY



Sensitivity of risk of decline to adult survival (S_a). The curves show the probability of falling below the metapopulation threshold as a function of time. The vertical dashed lines show the median time to decline. The arrows show four sensitivity results: the difference between median time to decline (A), the difference in risk of decline in 20 years (B) and 50 years (C), and the maximum difference in risk of decline (D), which in this case occurred around year 30.

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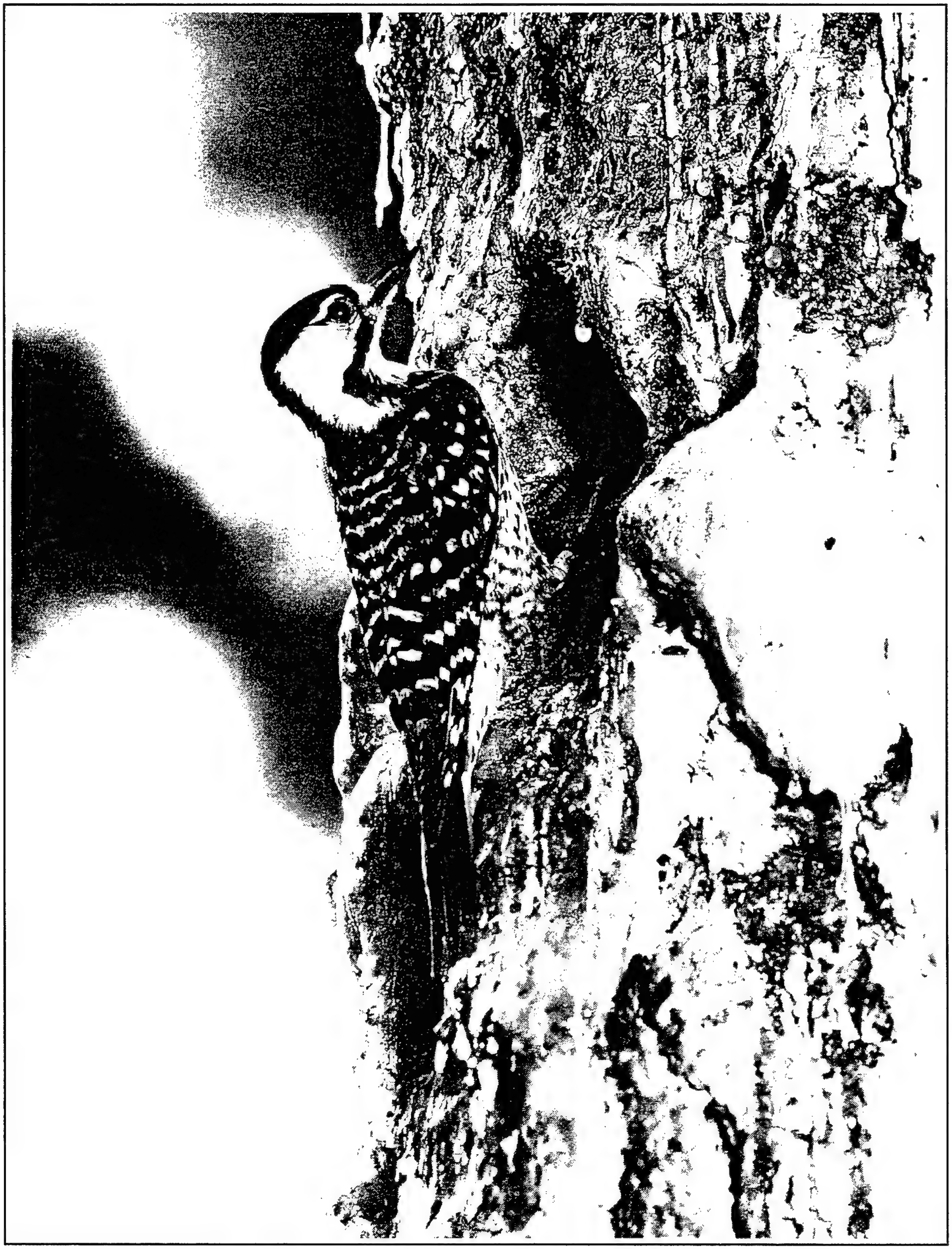
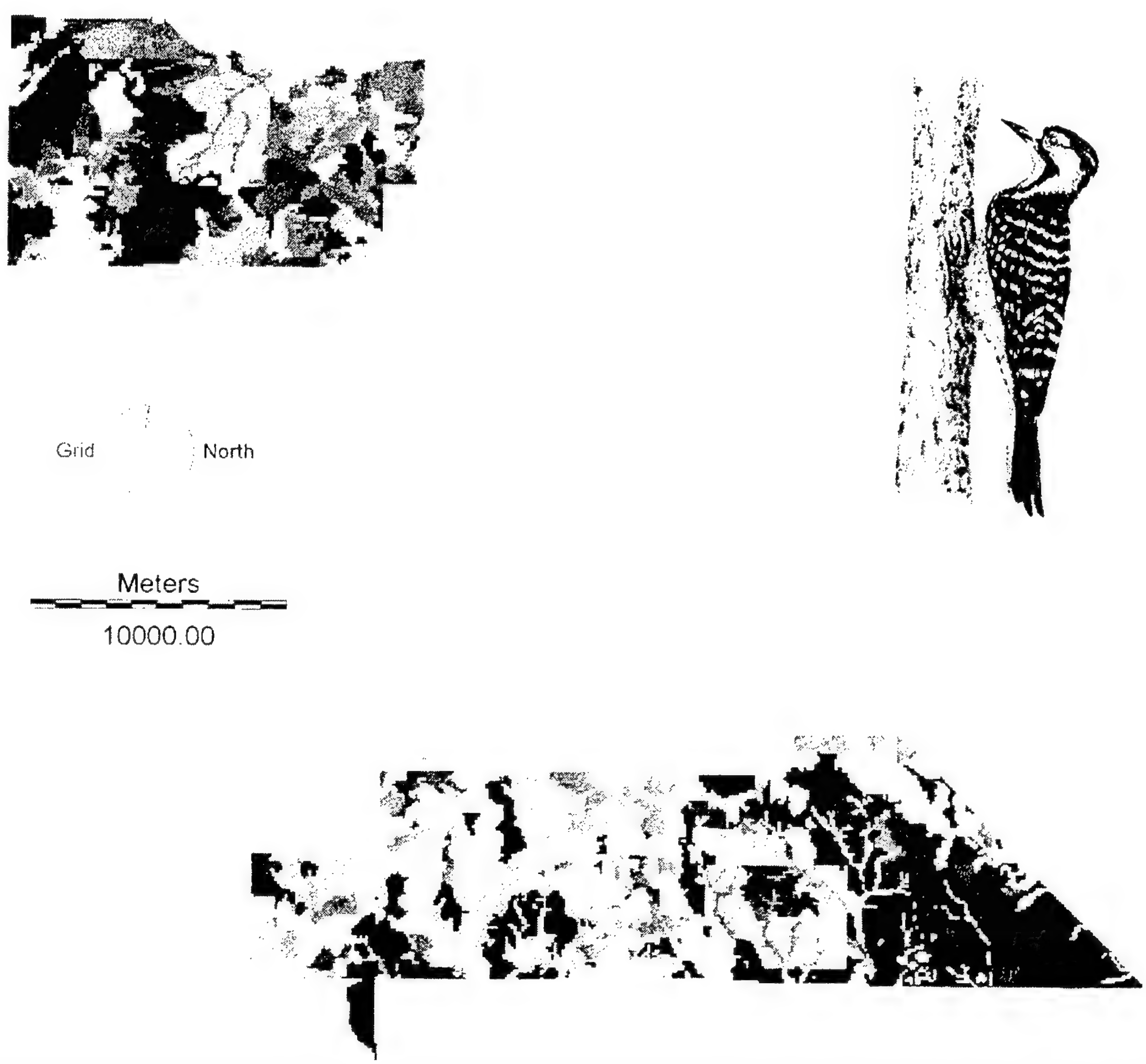
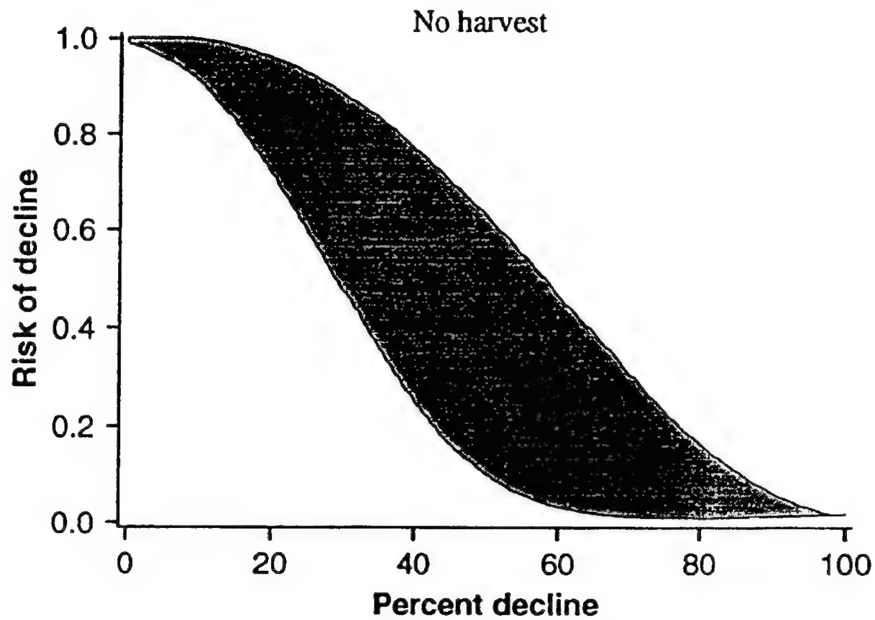


Red-cockaded Woodpecker habitat (1995)

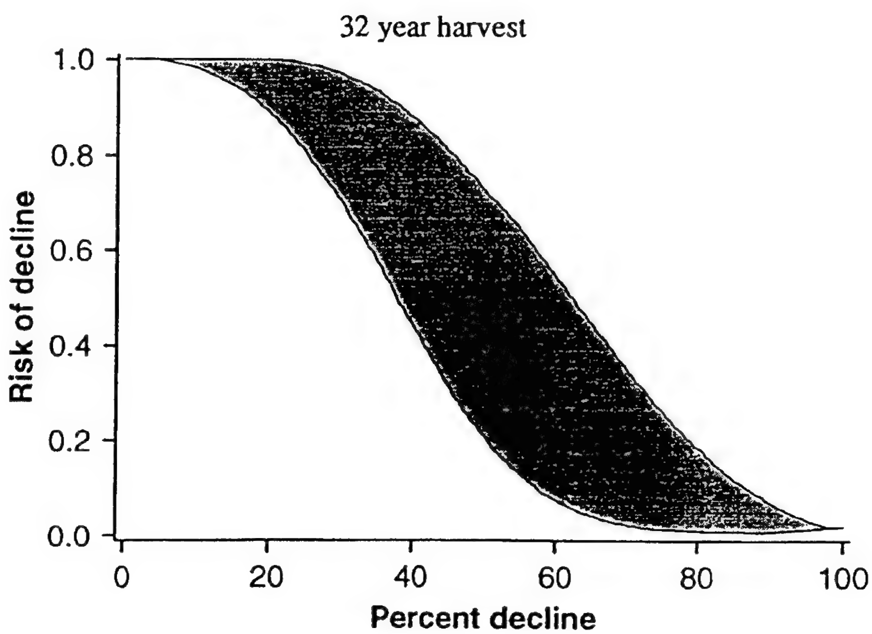


Red-cockaded Woodpecker habitat (2026)

Uncertainty in Risk of Decline of the Red-cockaded Woodpecker Populations at Fort Polk

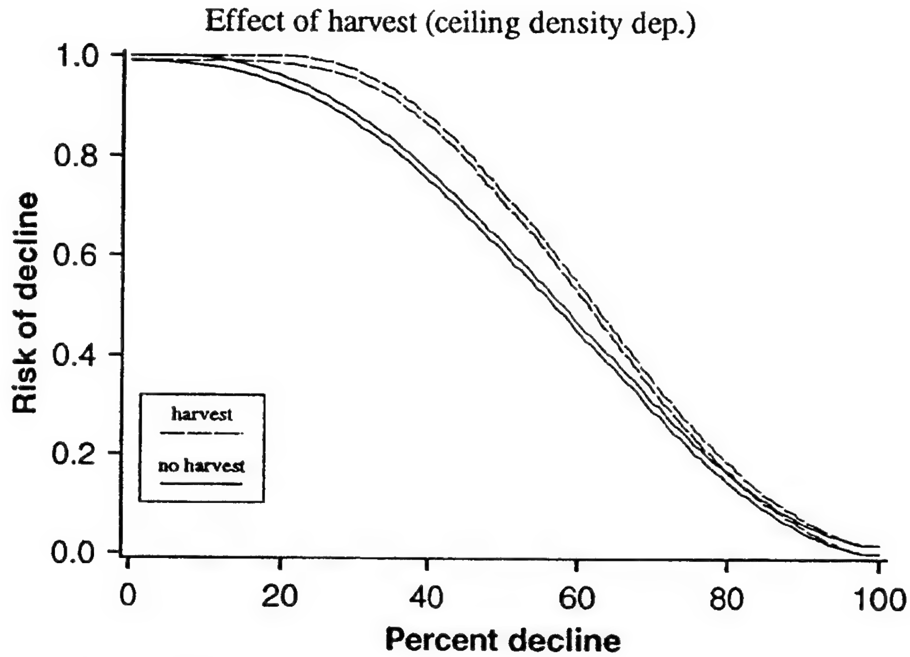


Risk of decline in 60 years with no timber harvest.

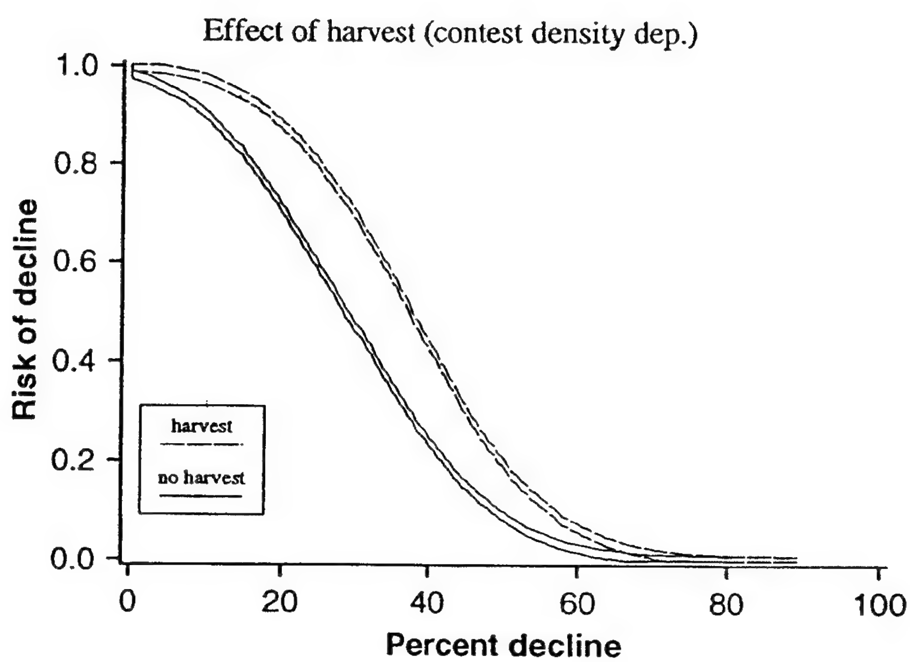


Risk of decline in 60 years with timber harvest from 1995 to 2026.

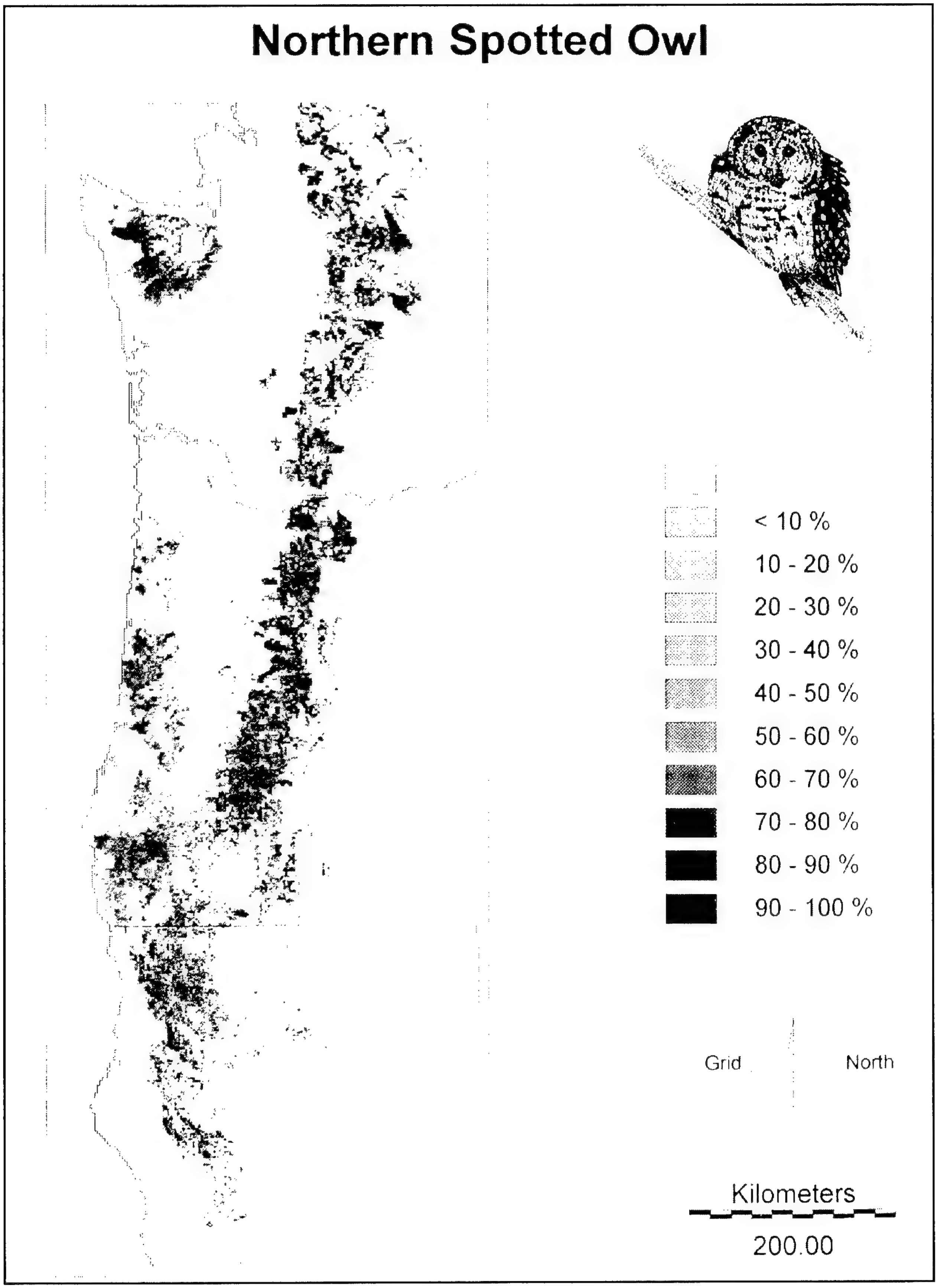
Impact Assessment Despite Uncertainty



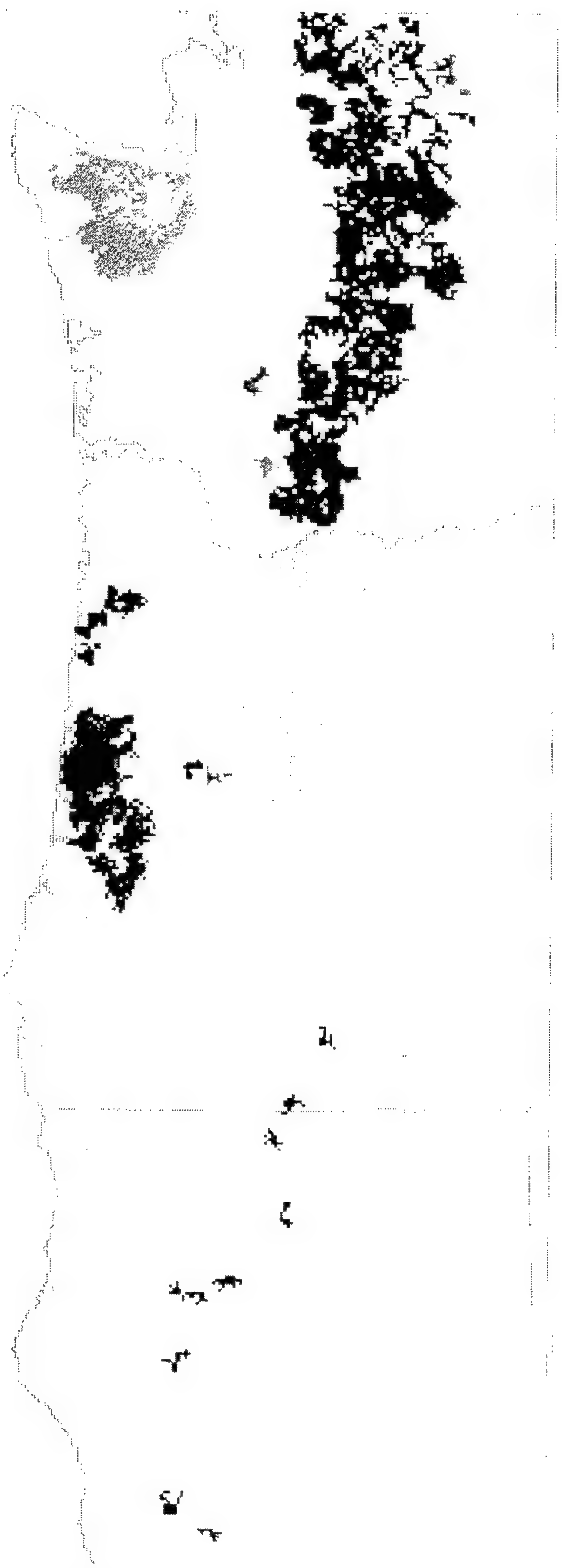
Effect of timber harvest under the Ceiling Model.

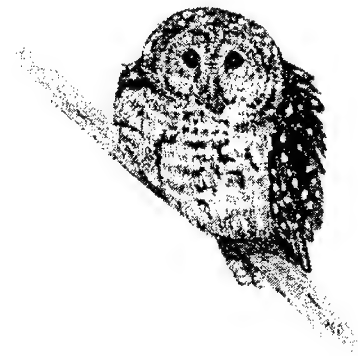


Effect of timber harvest under the Contest Model.


Northern Spotted Owl
< 10 %
10 - 20 %
20 - 30 %
30 - 40 %
40 - 50 %
50 - 60 %
60 - 70 %
70 - 80 %
80 - 90 %
90 - 100 %
Grid
North
Kilometers
200.00

Northern Spotted Owl Metapopulation





Habitat patches found by RAMAS GIS, based on the distribution of suitable spotted owl habitat (Akçakaya and Raphael 1998)

Akçakaya, H.R. and M.G. Raphael (1998) Assessing Human Impact Despite Uncertainty: Viability of the Northern Spotted Owl Metapopulation in the Northwestern U.S. *Biodiversity and Conservation* (in press).

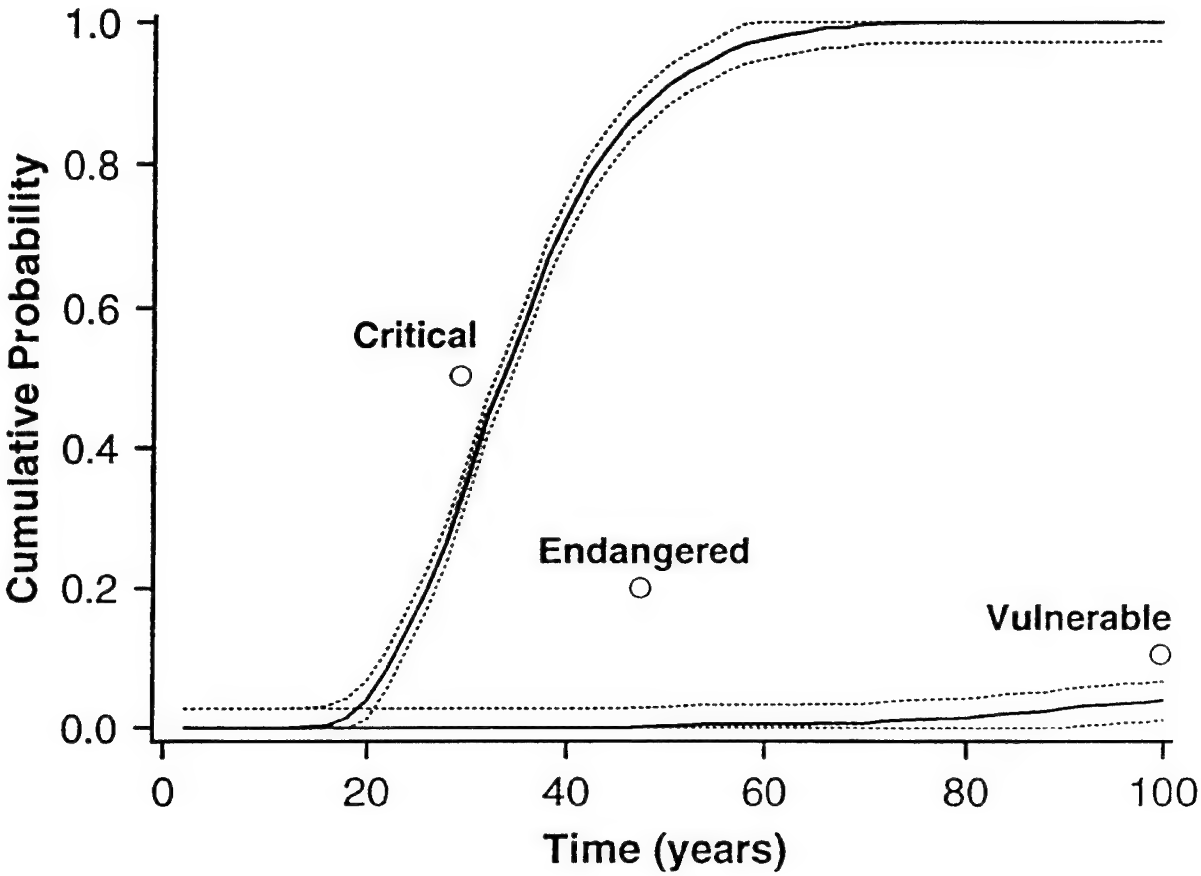
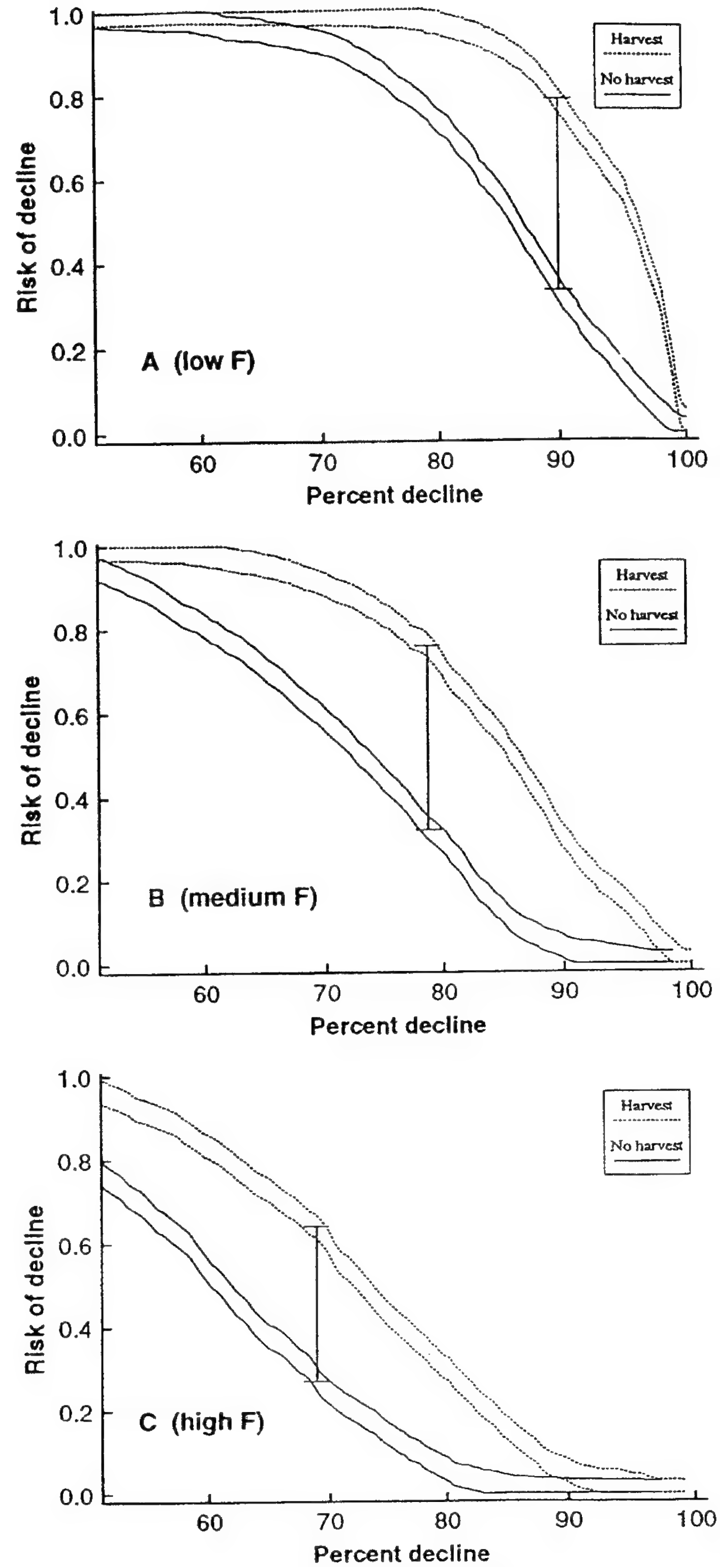


Figure 5. Time to extinction with the mid-range parameters (curves close to the x-axis), and with a pessimistic scenario. The thick curves show the cumulative probability that the metapopulation abundance will fall below the extinction threshold (530 owls) at or before a given year. The dotted curves show 95% confidence interval of the risk curve, and the circles indicate IUCN's risk-based criteria for categories of threat (see text).

Akçakaya, H.R. and M.G. Raphael (1998) Assessing Human Impact Despite Uncertainty: Viability of the Northern Spotted Owl Metapopulation in the Northwestern U.S. *Biodiversity and Conservation* (in press).



FUTURE DIRECTIONS IN METAPOPULATION MODELING

Multispecies Assessments

- habitat suitability maps for several species in the same landscape
- composite map with weighted average of all single-species maps
- ***Assessment:***
  - "conservation value" of predefined parcels
  - identifying patches or locations with high "multispecies habitat suitability"
- ***Issues:***
  - identifying "representative" or "indicator" species
  - determining weights (e.g., based on extinction risk)

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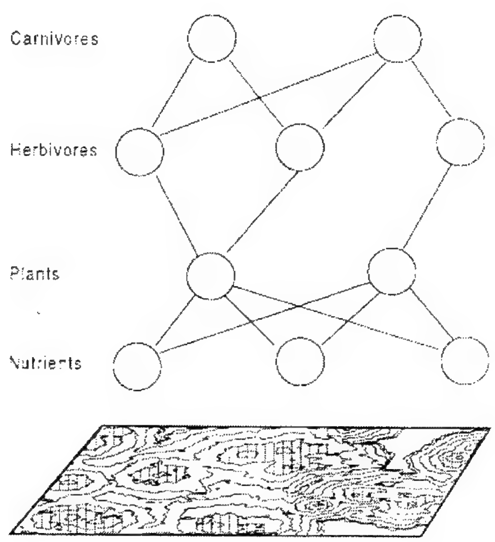
FUTURE DIRECTIONS IN METAPOPULATION MODELING

Community-metapopulation Models

- each trophic level represented as a metapopulation
- each metapopulation at a different spatial scale
- connections between metapopulations based on energy flow
- ***Issues:***
  - coordinating multiple spatial and temporal scales
  - determining trophic relationships (predation function, etc.)
  - identifying functional groups (trophic level, guild, species)



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Appendix J
Ecological Risk in an Integrated Intermedia System

This appendix contains the presentation documents for "Ecological Risk in an Integrated Intermedia System" by Gene Whelan - Battelle Pacific Northwest National Laboratory.

Ecological Risk in an Integrated Intermedia System

G. Whelan, Ph.D.

Pacific Northwest National Laboratory

Richland, WA

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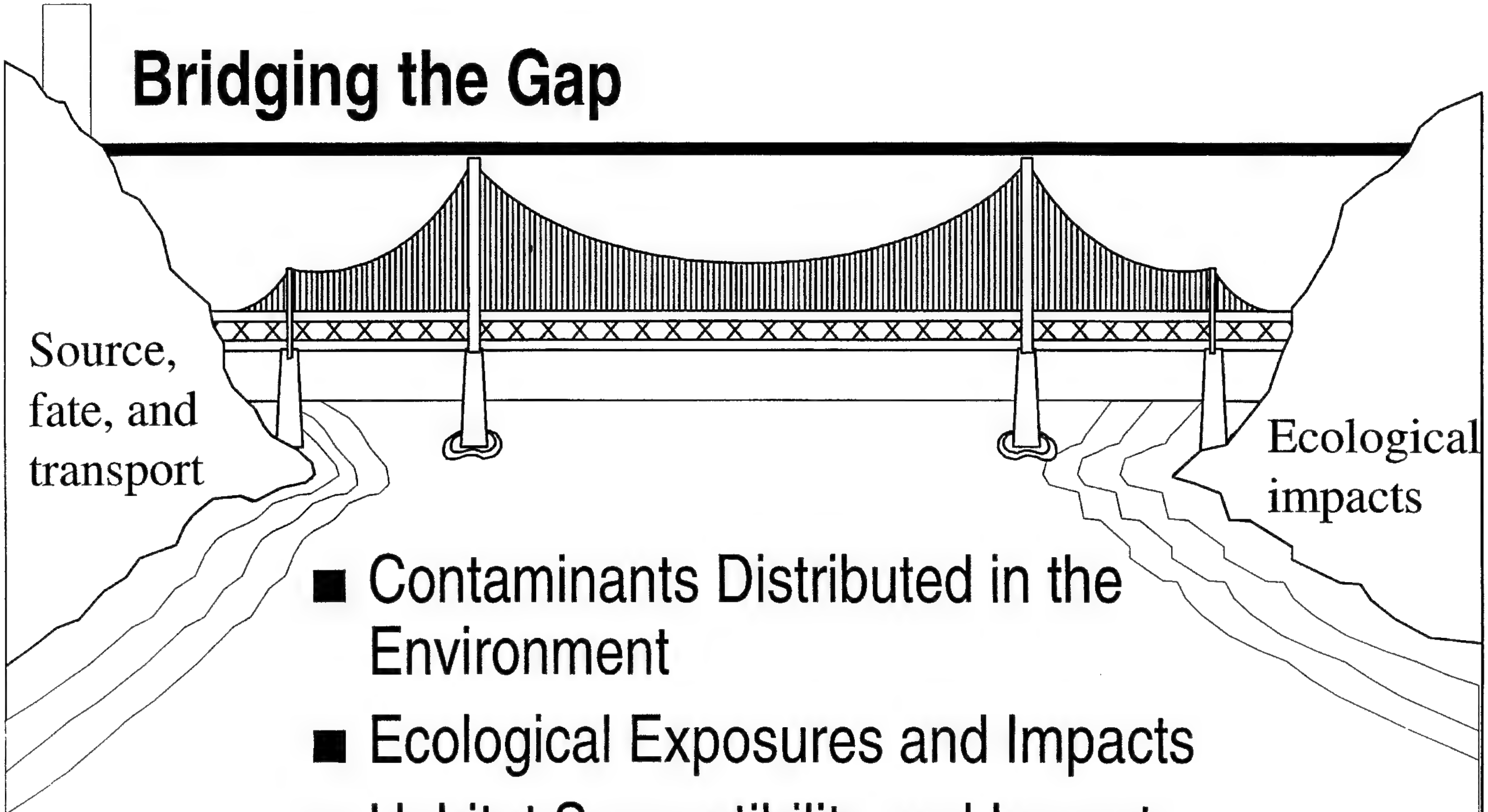
Bridging the Gap



- Contaminants Distributed in the Environment
- Ecological Exposures and Impacts
- Habitat Susceptibility and Impacts

Phased Approach

- Varying Levels of Detail to Match Tools to Assessment Needs
- Preliminary Assessment
- Detailed Assessment

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Illustrative Ecological Models

- Wildlife Ecological Assessment Program (WEAP)
- Ecological Contaminant Exposure Model (ECEM)
- Health and Ecological Risk Management and Evaluation System (HERMES)
- Framework for Risk Analysis in Multimedia Environmental Systems (FRAMES)

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"WEAP"

Wildlife Exposure Assessment Program

Ecological Exposure Assessment Modeling with Frequency Analysis

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WEAP

- Represents a Preliminary Assessment
- Correlates Exposure and Effect, using Laboratory Data
- Analyzes and Correlates Concentration and Duration of Exposure
- Accounts of Frequency of Occurrence

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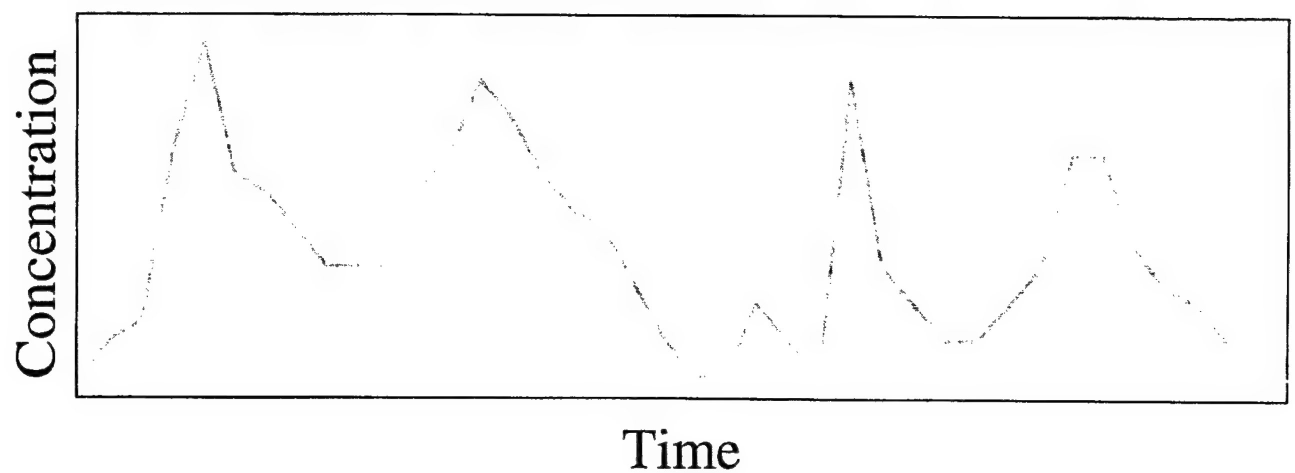
Example of an Aquatic Assessment

- Fate & Transport Modeling
- Selected Locations
- Time Varying Concentration Curves



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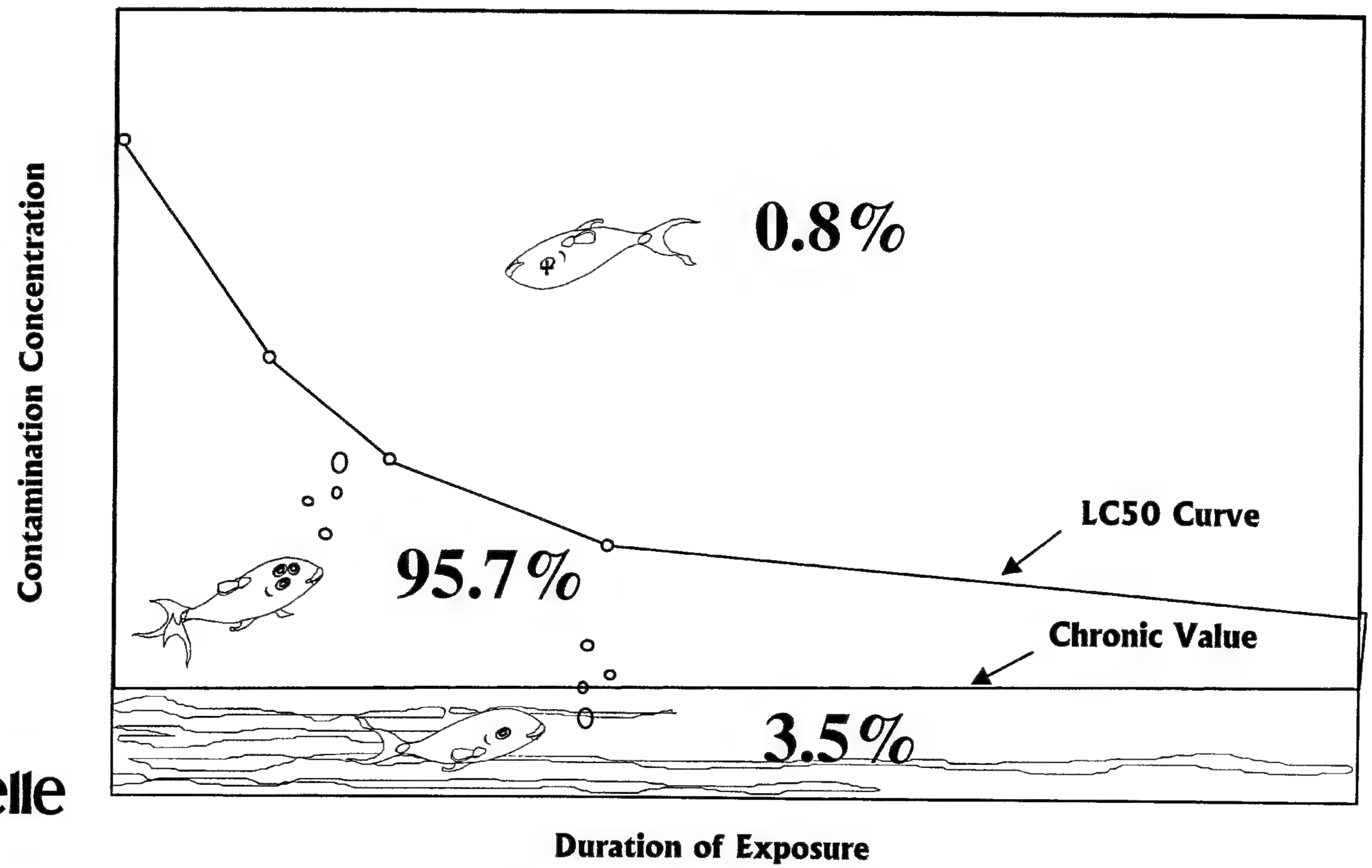
Brown Trout Exposed to Cadmium
(Whitewood Creek Results)



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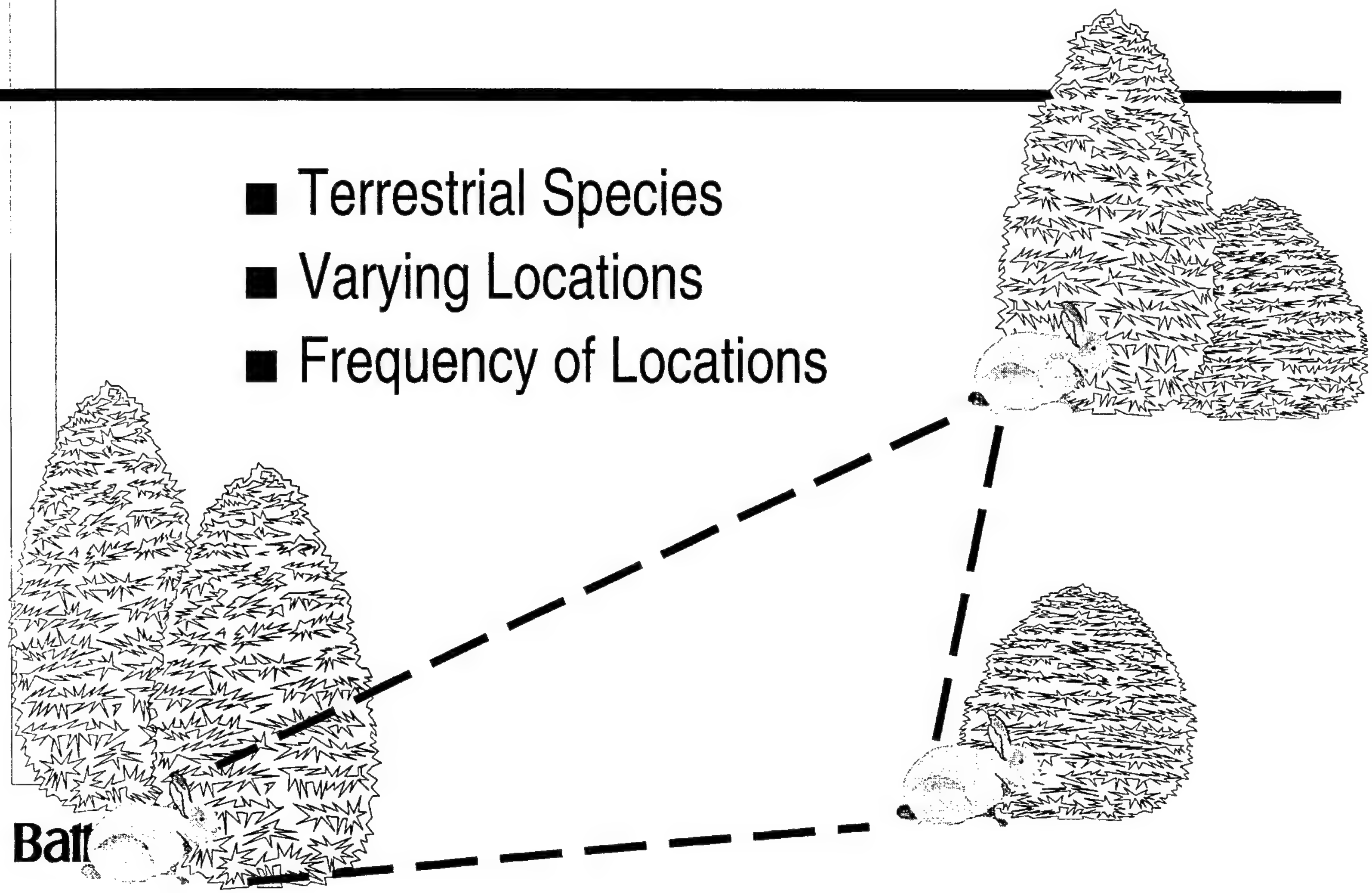
Beyond Aquatic Assessments

- Terrestrial Species
- Varying Locations
- Frequency of Locations



"ECEM"

Ecological Contaminant Exposure Model

A Food-Wed Based Ecological Exposure Assessment Tool

Battelle

Developed by
Pacific Northwest National Laboratory
for the U. S. Department of Energy

For information contact:

Charles A. Brandt, Ph.D.
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Richland, WA 99352
(509) 376-5345
charles.brandt@pnl.gov

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What is ECEM?

- An ecological risk assessment modeling tool
- Estimates exposures
  - from metals, organics, and/or radionuclides
  - in terrestrial and/or aquatic environments
- Based on a food-web architecture
- Helps environmental managers assess impacts as part of a regulatory or decision-making process

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How does ECEM work?

- User inputs
  - contaminants of interest
  - species of interest and species in food web
  - environmental data (e.g., contaminant concentrations in air, water and soil)
- Results of the model are
  - body burden or dose rate
  - compared to environmental benchmarks to calculate the environmental hazard quotient, or
  - used as input into human health assessments

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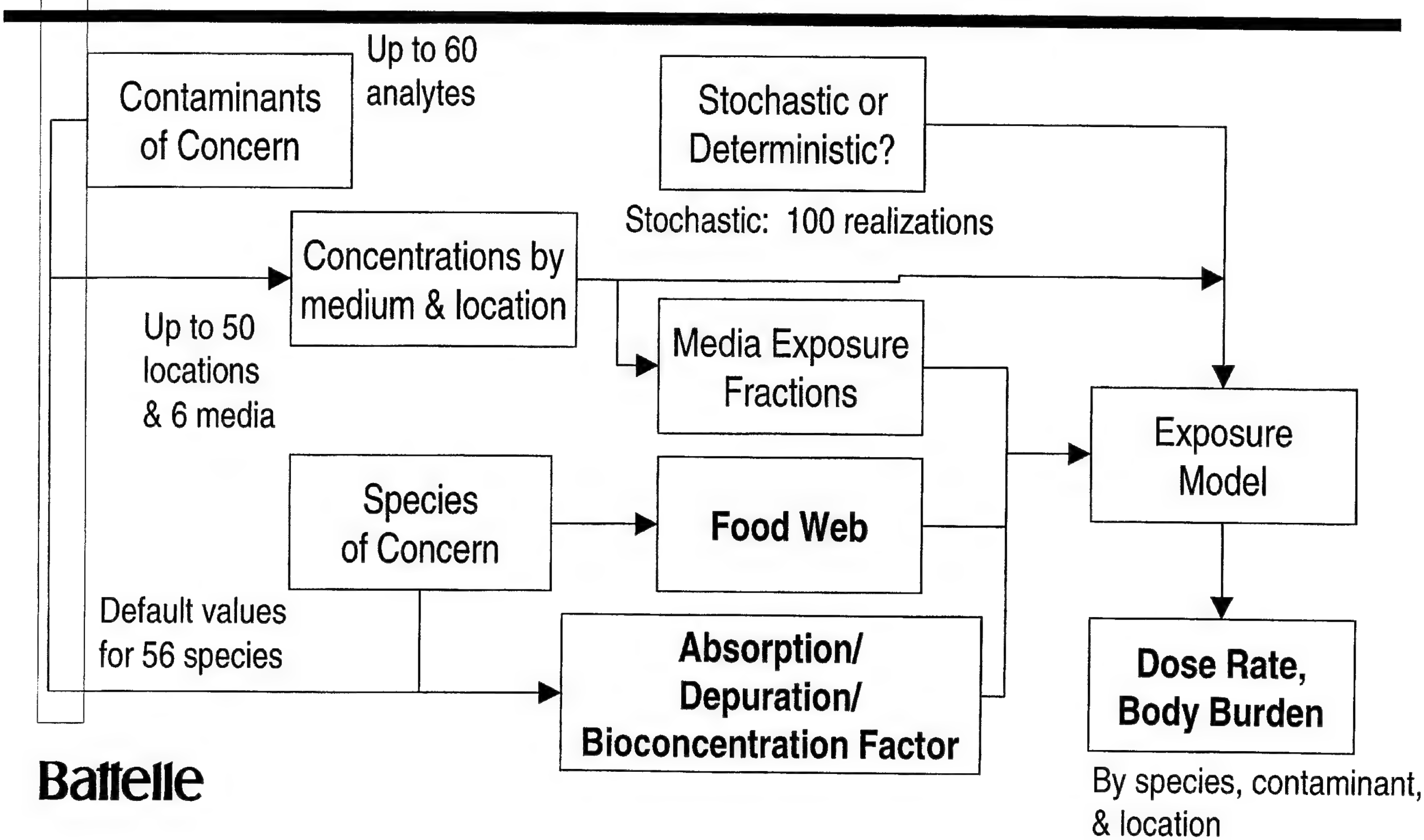
Structure of ECEM



Let's go through an example........

What is the problem to be assessed?

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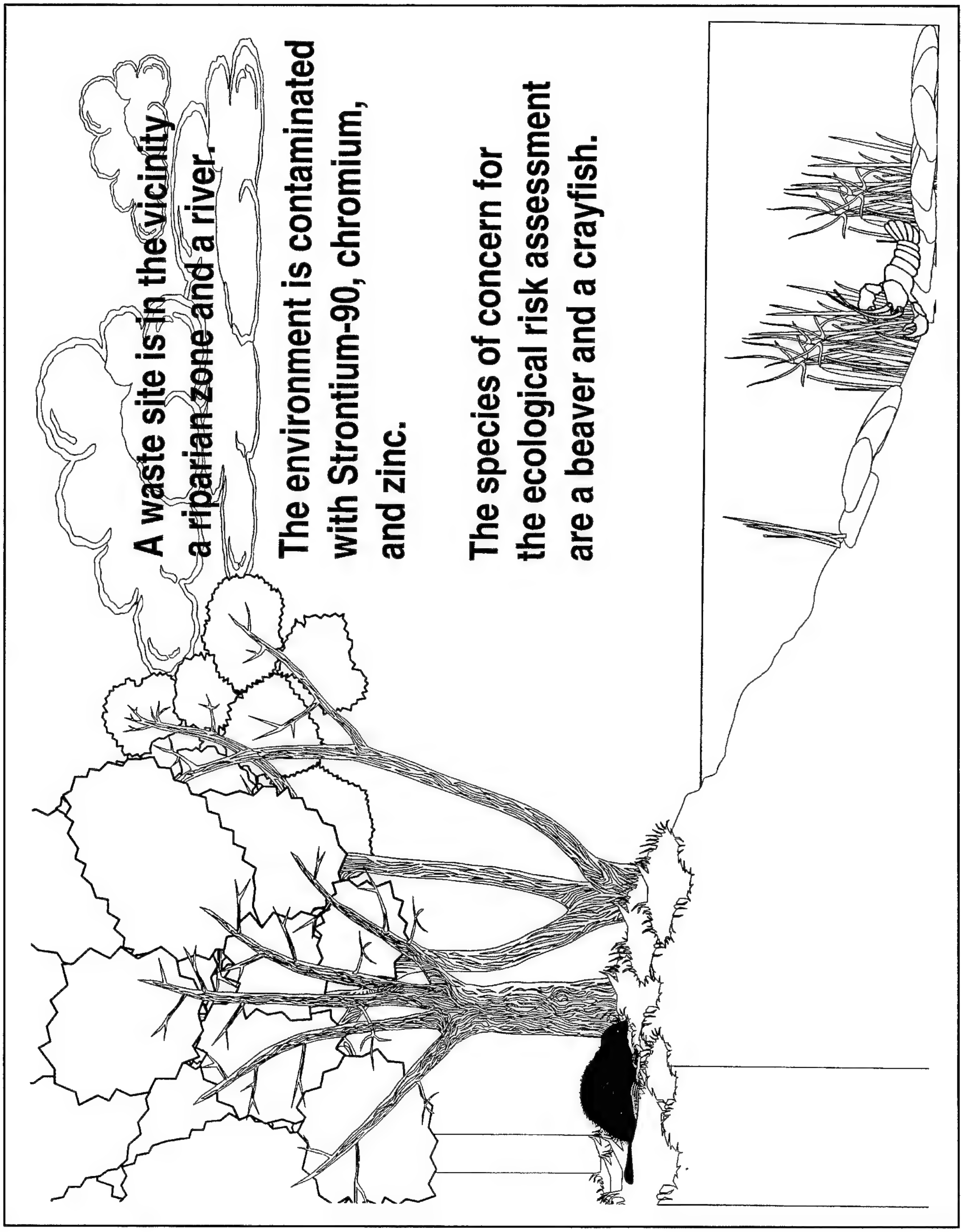
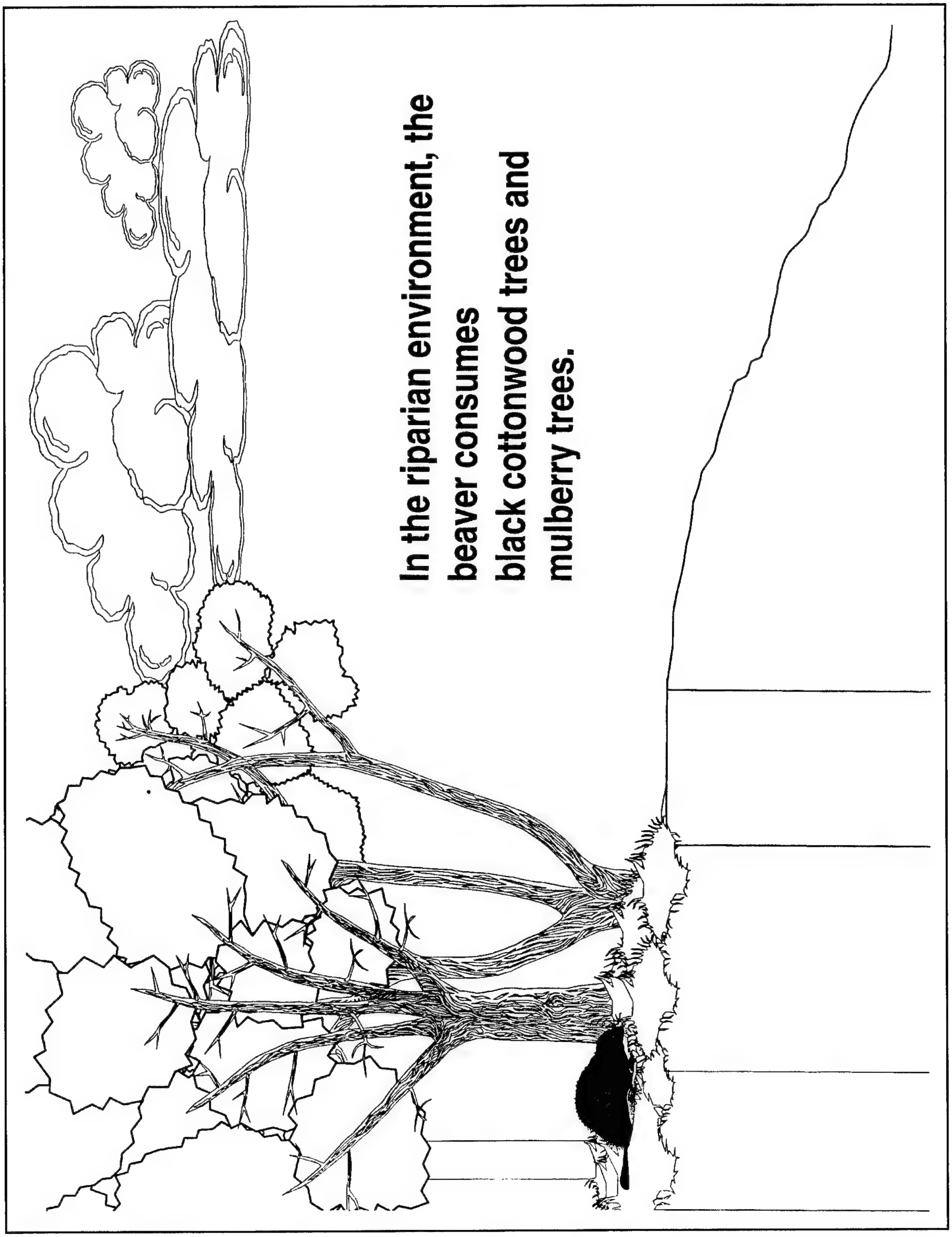
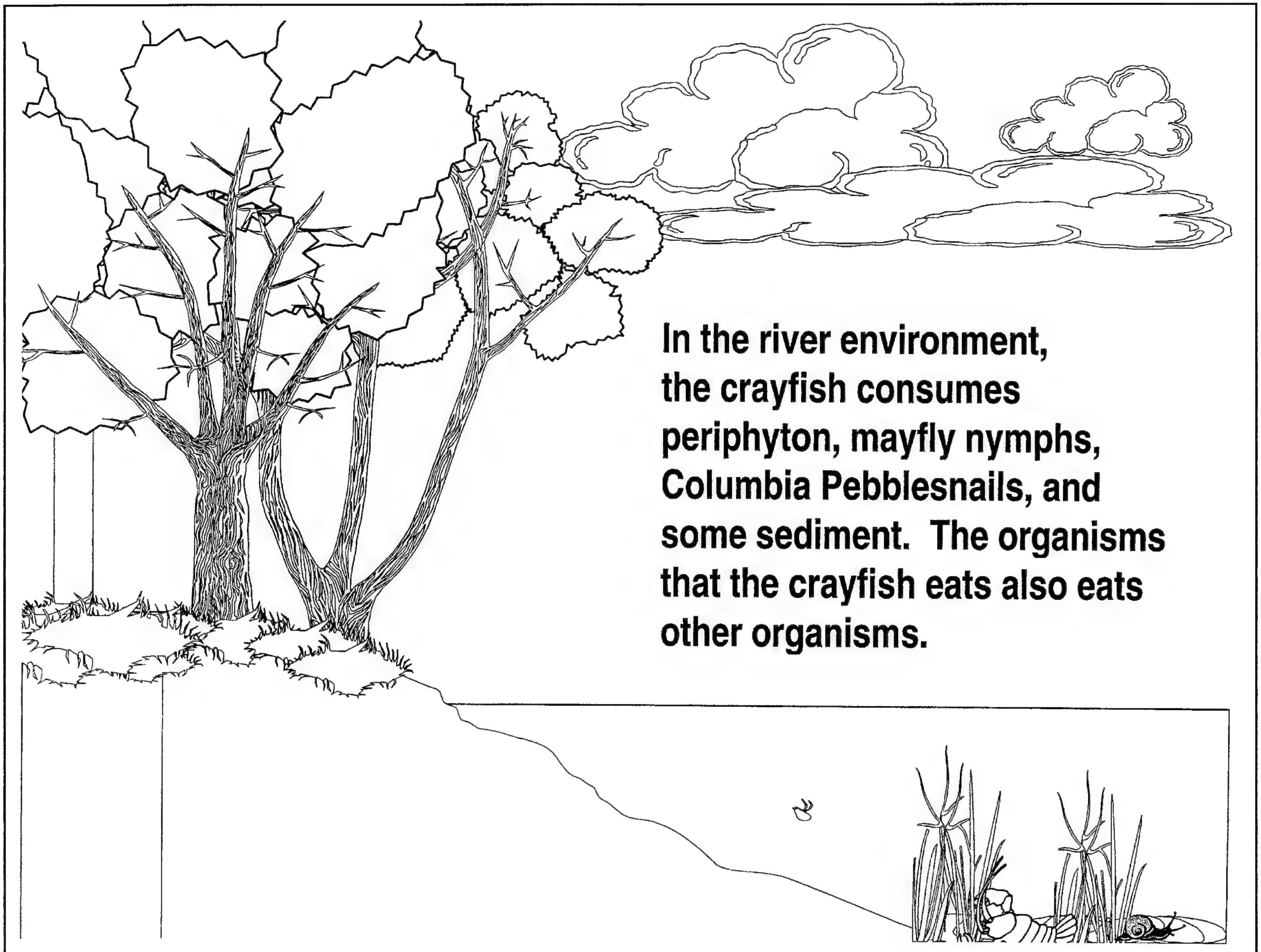

A waste site is in the vicinity a riparian zone and a river.
The environment is contaminated with Strontium-90, chromium, and zinc.
The species of concern for the ecological risk assessment are a beaver and a crayfish.


In the riparian environment, the
beaver consumes
black cottonwood trees and
mulberry trees.


In the river environment, the crayfish consumes periphyton, mayfly nymphs, Columbia Pebblesnails, and some sediment. The organisms that the crayfish eats also eats other organisms.

That is, the food web definitions are:

- Crayfish Consumption
  - 30% Sediment
  - 50% Periphyton
  - 10% Mayfly
    - 10% Sediment
    - 30% Phytoplankton
    - 40% Periphyton
    - 12% Water Millfoil
    - 4% Hyallela
    - 4% Daphnia Magna
  - 10% Columbia Pebblesnail
    - 10% Sediment
    - 80% Periphyton
    - 10% Water Millfoil
- Beaver Consumption
  - 50% Black Cottonwood
  - 50% Mulberry

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The environmental data for this example:

- Media Data
  - Pore Water
  - Surface Water
  - Sediment
  - Soil
- Internally-Calculated Concentrations
  - Air Vapor
  - Air Particulate

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Now that we have the basic problem defined,

Let's start the model.........

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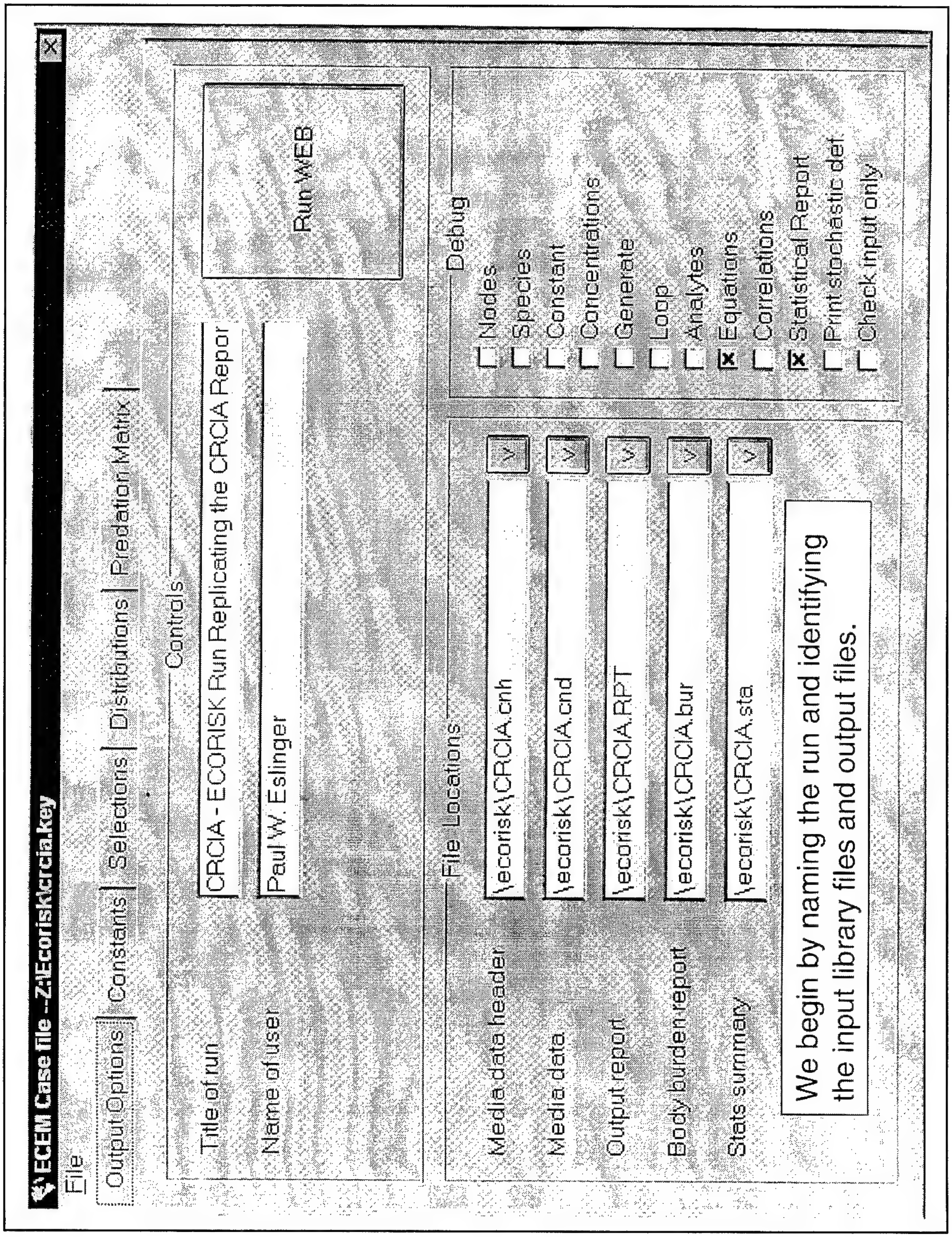
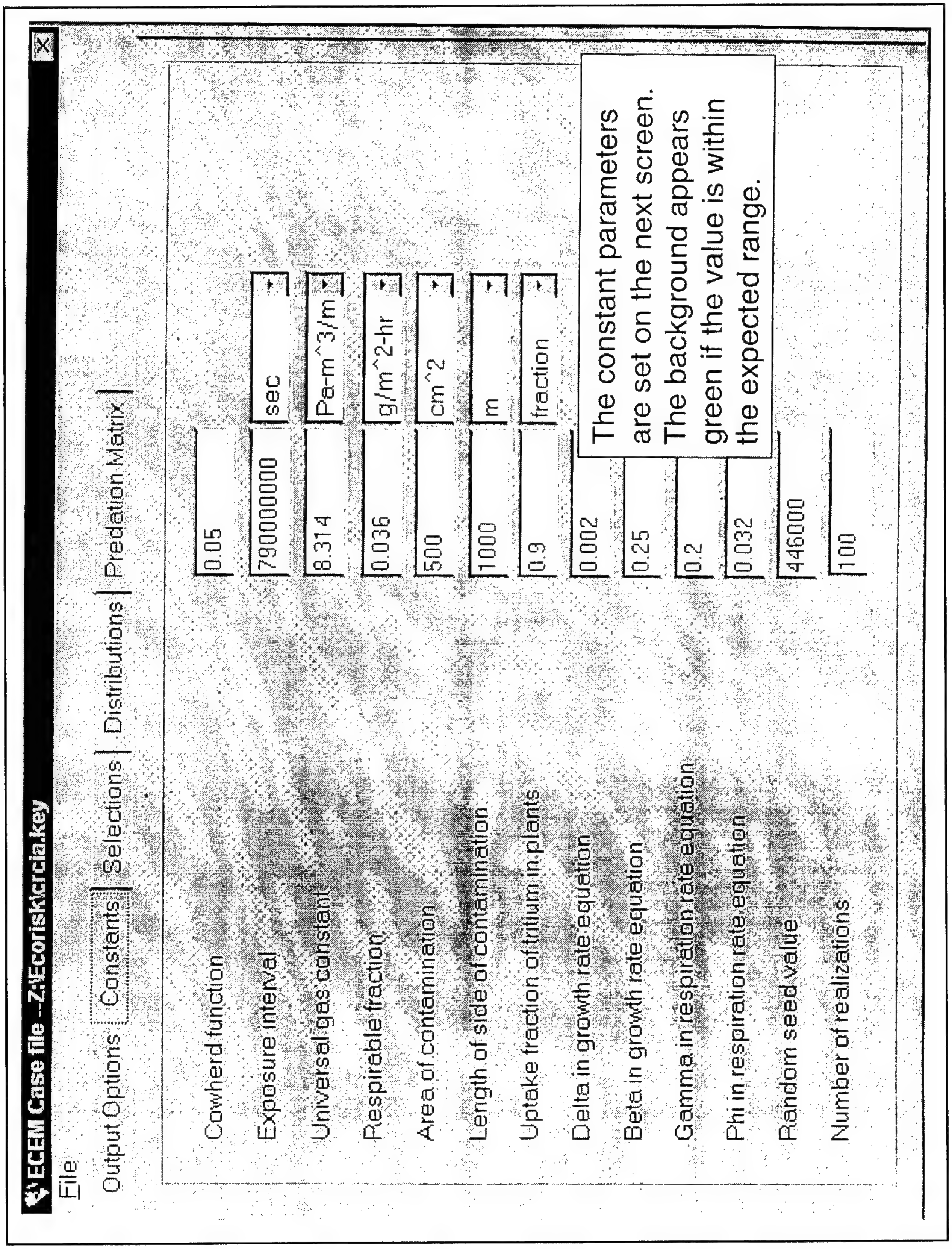
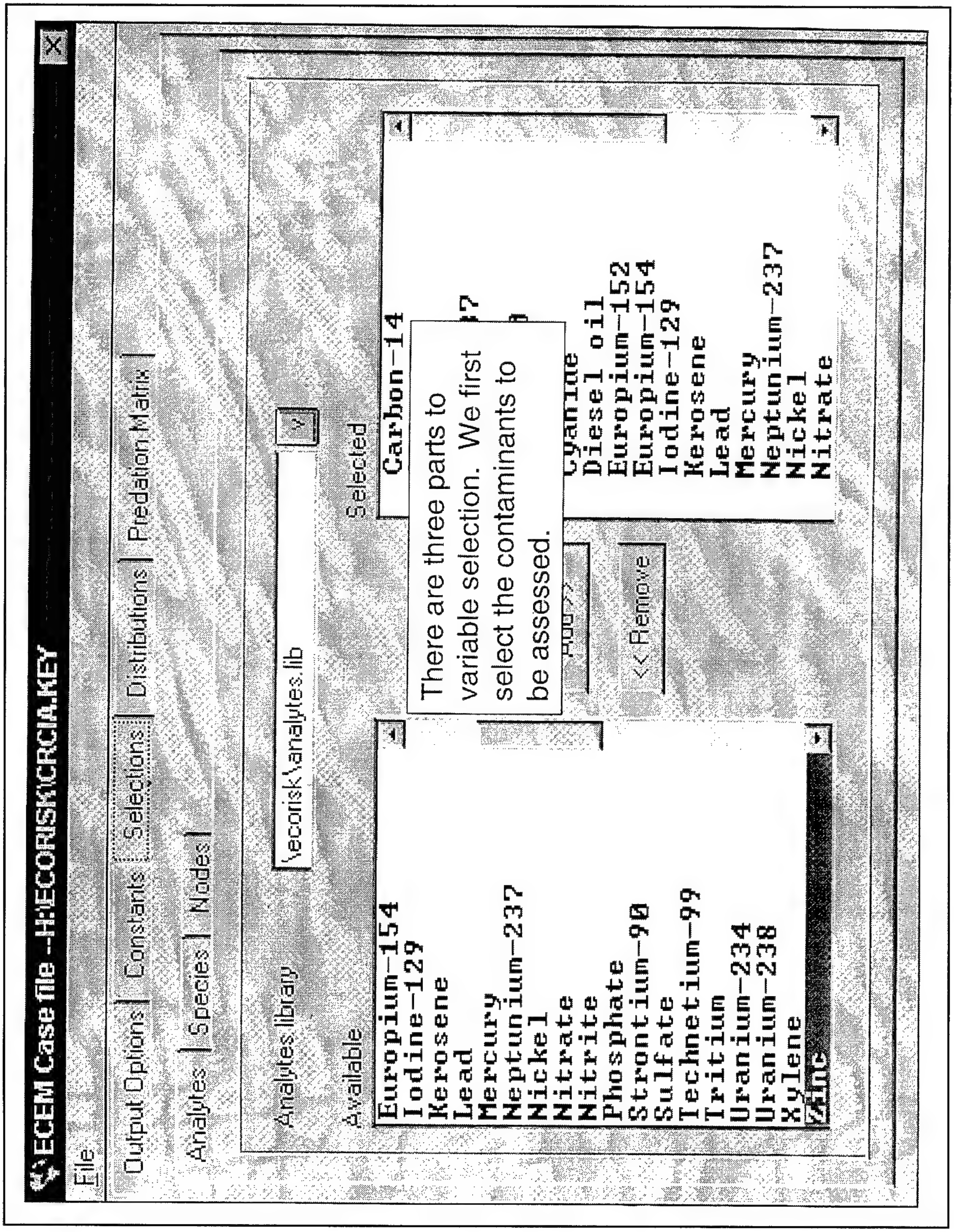
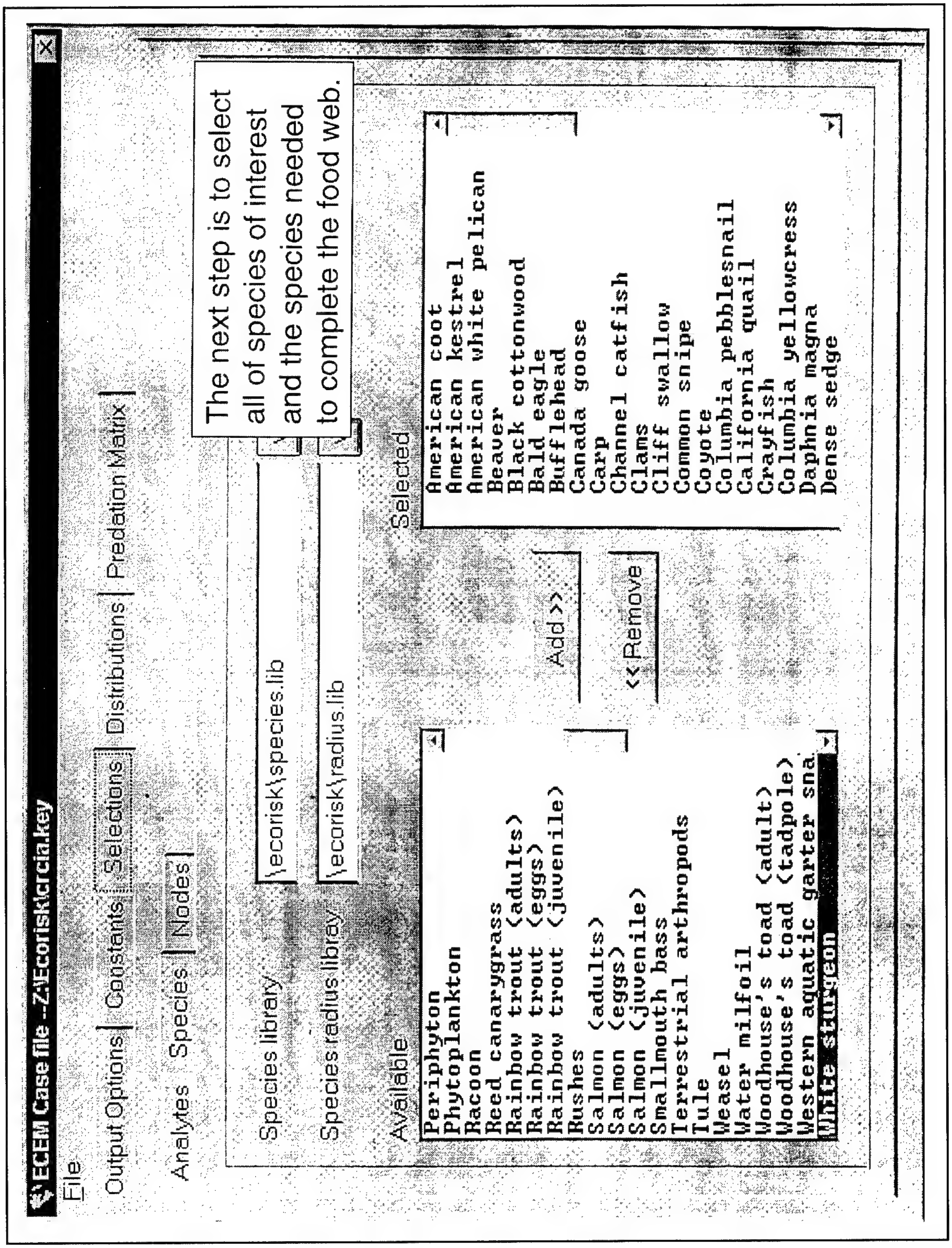
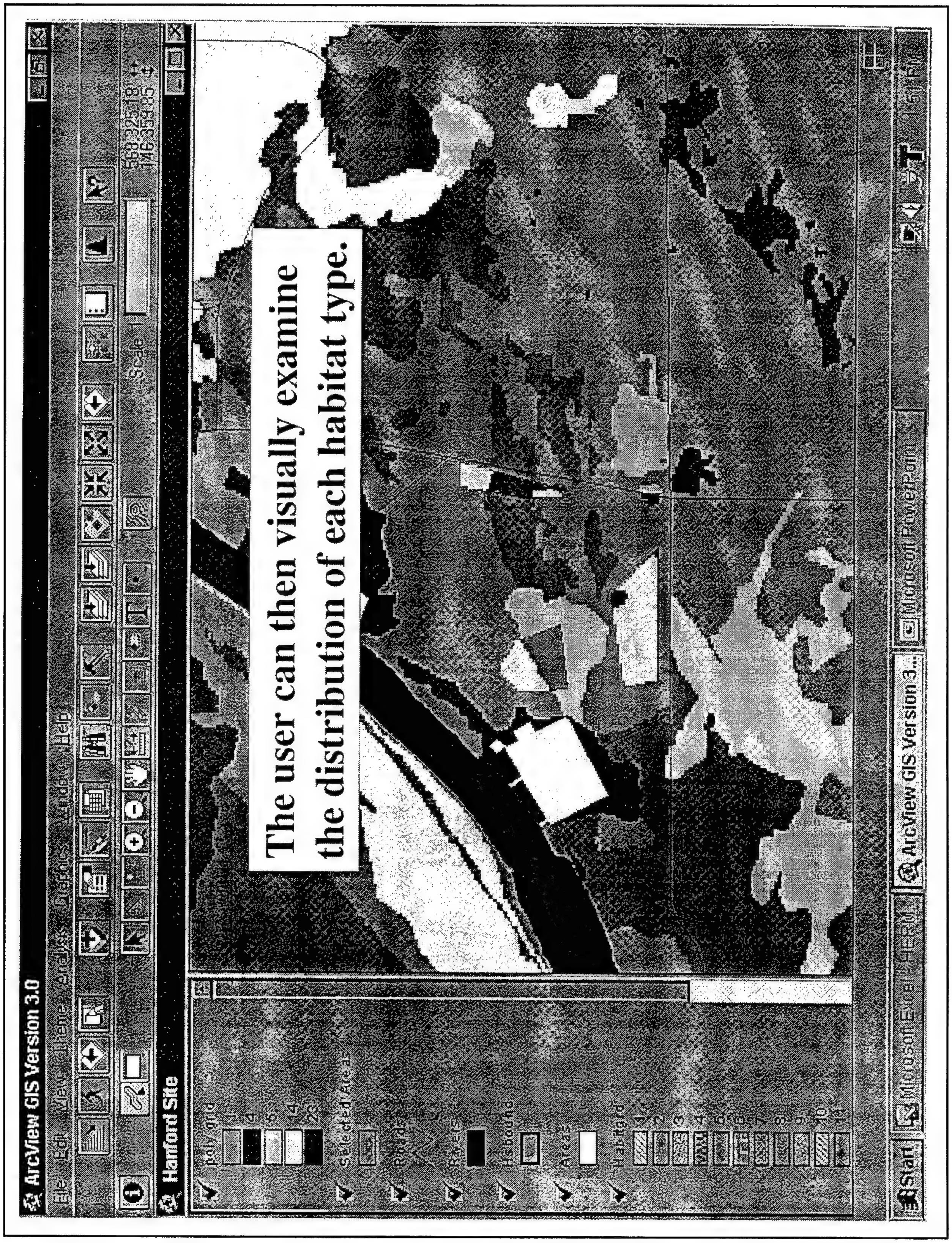
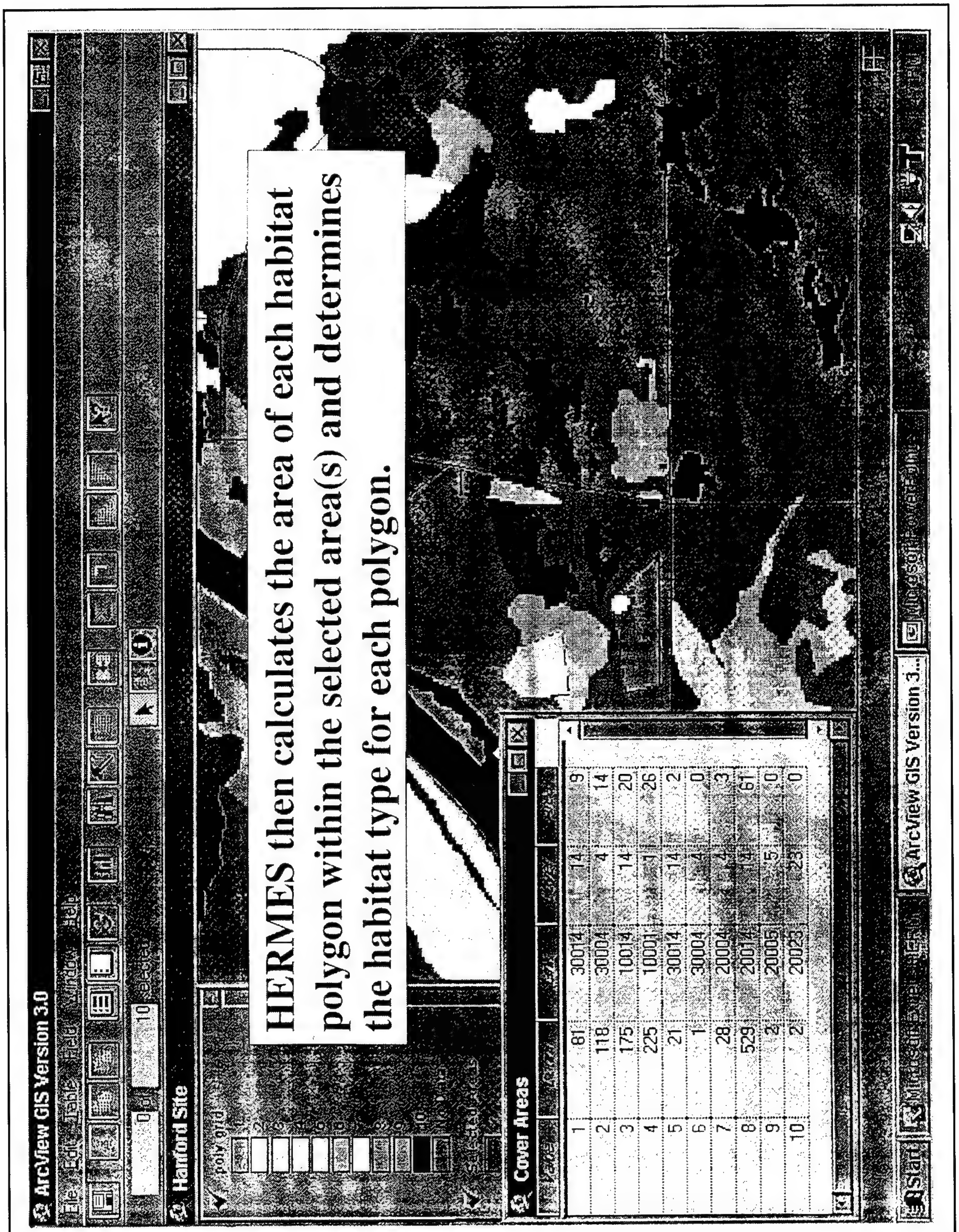

ECEM Case file --Z:\Ecorisk\crcia.key
File
Output Options
Constants
Selections
Distributions
Predation Matrix
Controls
Title of run
CRCIA - ECORISK Run Replicating the CRCIA Repor
Name of user
Paul W. Eslinger
Run WEB
File Locations
Media data header
\ecorisk\CRCIA.cnh
Media data
\ecorisk\CRCIA.cnd
Output report
\ecorisk\CRCIA.RPT
Body burden report
\ecorisk\CRCIA.bur
Stats summary
\ecorisk\CRCIA.sta
Debug
Nodes
Species
Constant
Concentrations
Generate
Loop
Analytes
Equations
Correlations
Statistical Report
Print stochastic det.
Check input only
We begin by naming the run and identifying the input library files and output files.

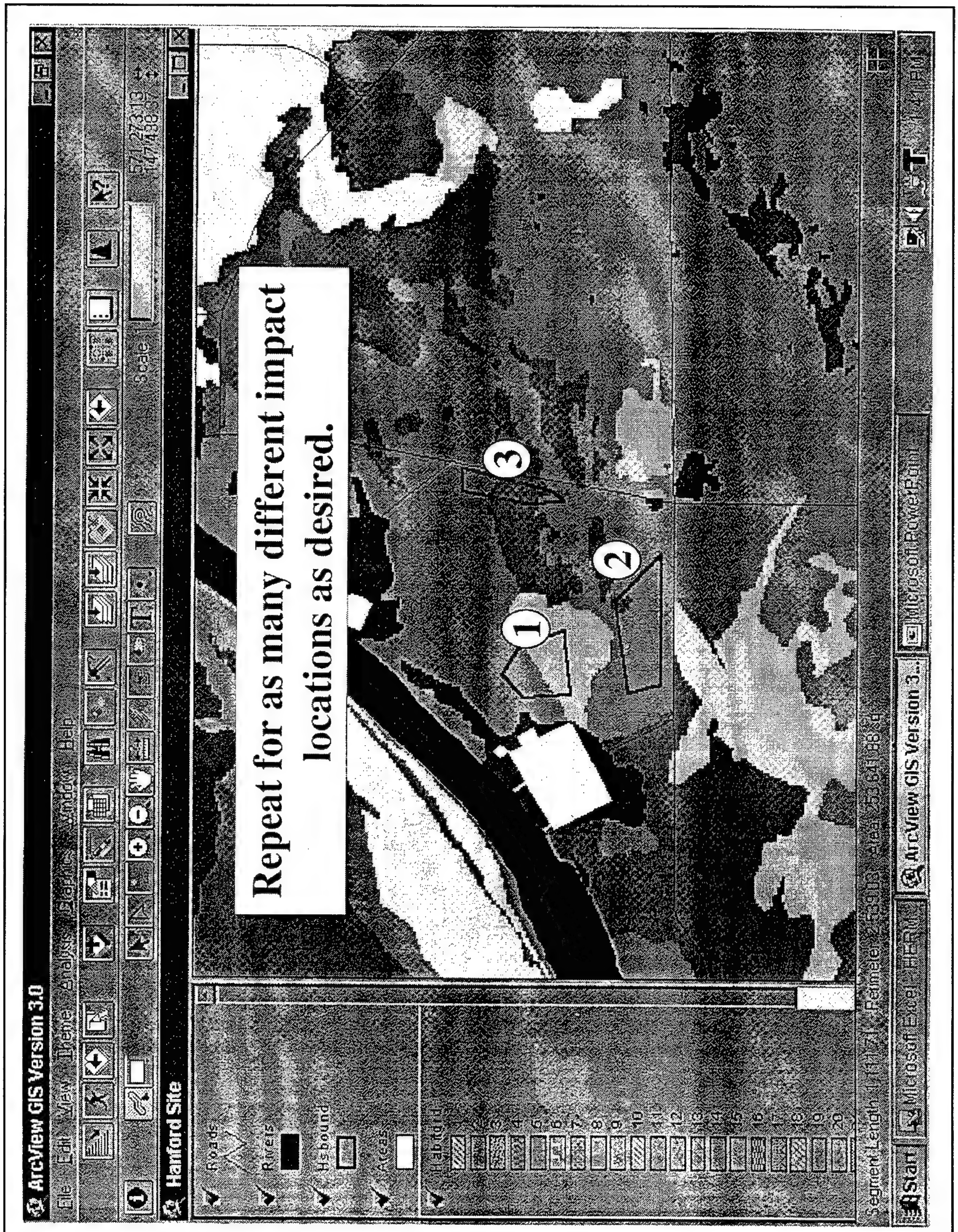

ECEM Case file --Z:\Ecorisk\crcia.key
File
Output Options
Constants
Selections
Distributions
Predation Matrix
Cowherd function
0.05
Exposure interval
790000000
sec
Universal gas constant
8.314
Pa-m^3/m
Respirable fraction
0.036
g/m^2-hr
Area of contamination
500
cm^2
Length of side of contamination
1000
m
Uptake fraction of tritium in plants
0.9
fraction
Delta in growth rate equation
0.002
Beta in growth rate equation
0.25
Gamma in respiration rate equation
0.2
Phi in respiration rate equation
0.032
Random seed value
446000
Number of realizations
100
The constant parameters are set on the next screen. The background appears green if the value is within the expected range.

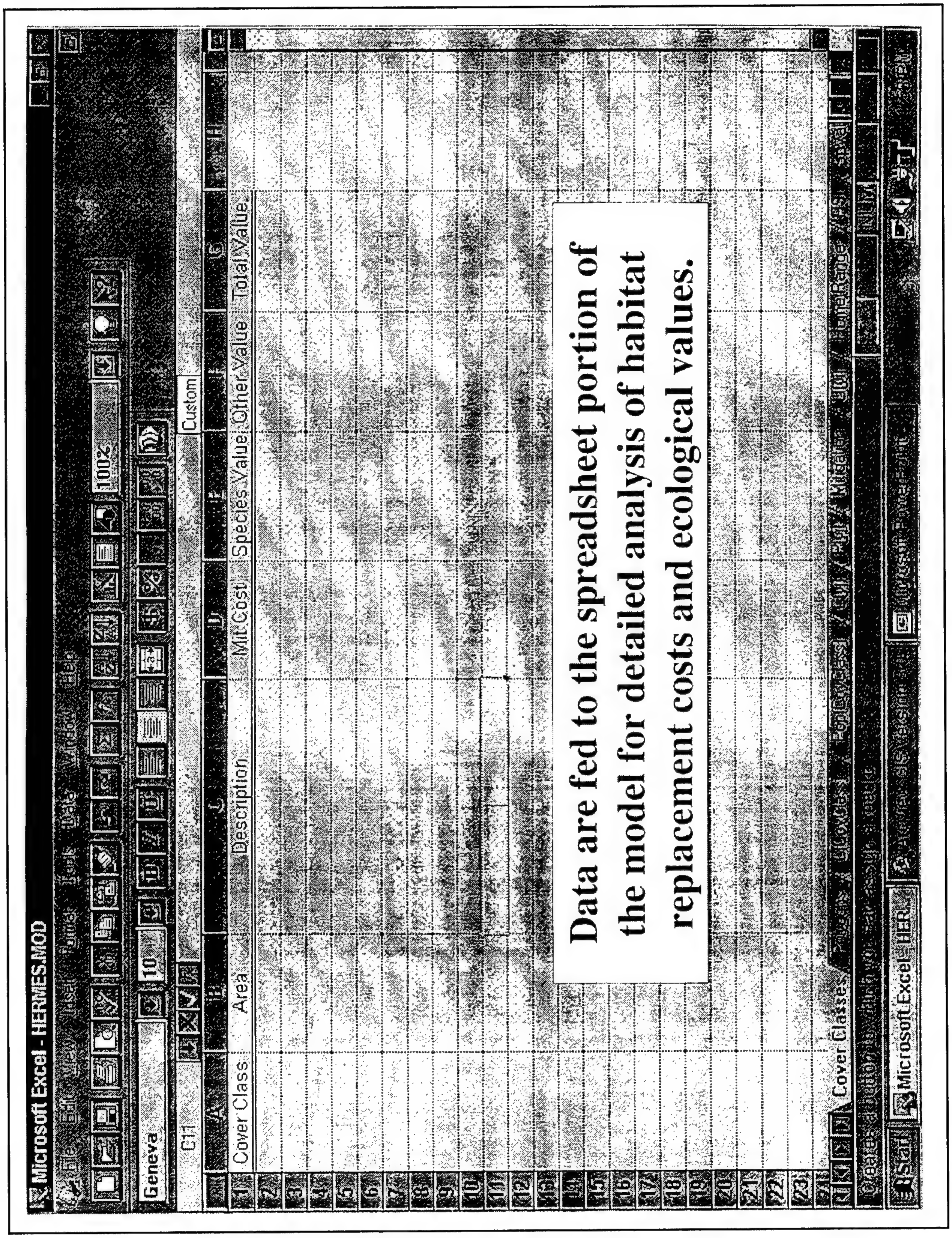

ECEM Case file --H:\ECORISK\CRCIA.KEY
File
Output Options
Constants
Selections
Distributions
Predation Matrix
Analytes
Species
Nodes
Analytes library
\ecorisk\analytes.lib
Available
Europium-154
Iodine-129
Kerosene
Lead
Mercury
Neptunium-237
Nickel
Nitrate
Nitrite
Phosphate
Strontium-90
Sulfate
Technetium-99
Tritium
Uranium-234
Uranium-238
Xylene
Zinc
<< Remove
Selected
Carbon-14
Cyanide
Diesel oil
Europium-152
Europium-154
Iodine-129
Kerosene
Lead
Mercury
Neptunium-237
Nickel
Nitrate
There are three parts to variable selection. We first select the contaminants to be assessed.

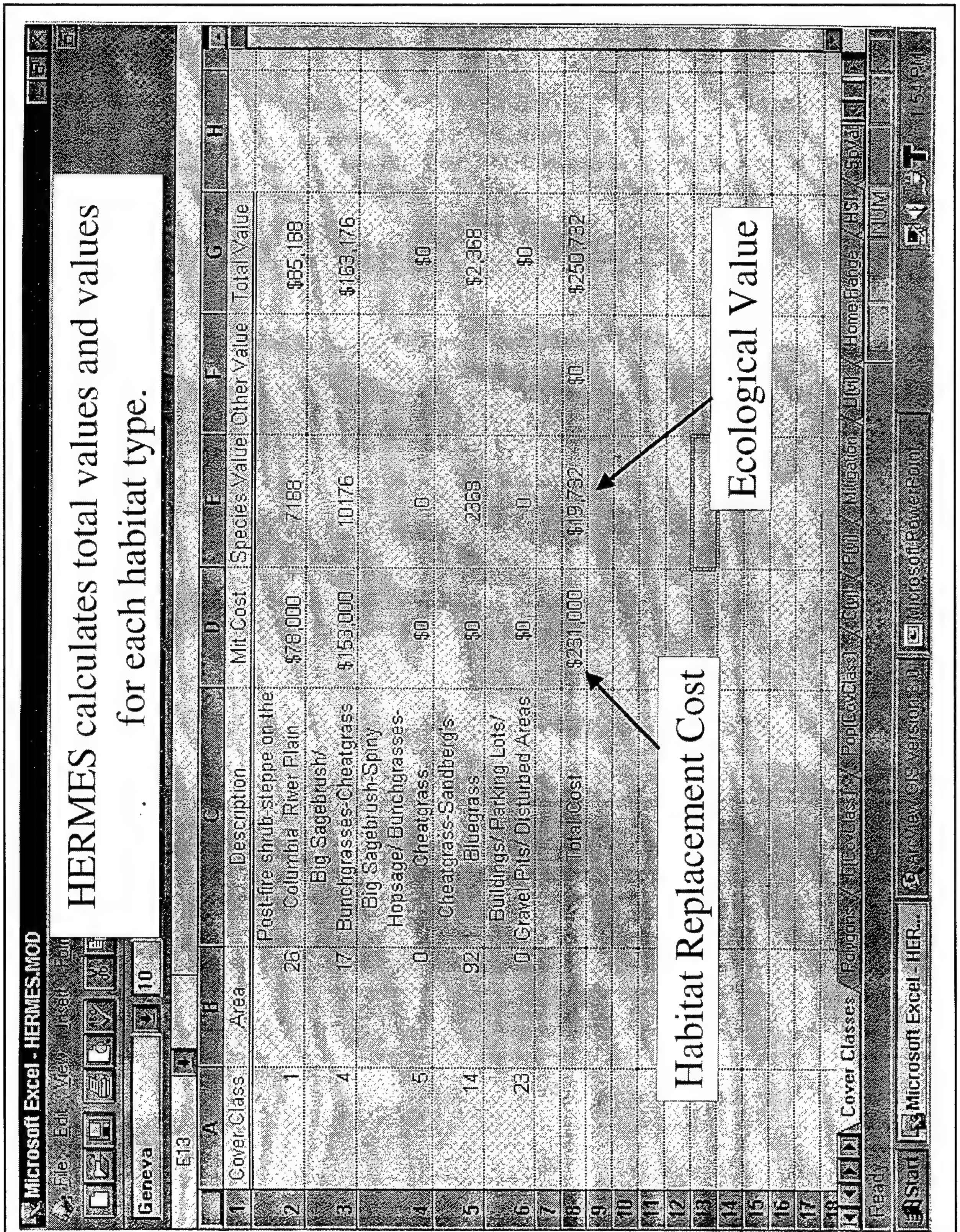

ECEM Case file --Z:\Ecorisk\crcia.key
File
Output Options
Constants
Selections
Distributions
Predation Matrix
Analytes
Species
Nodes
Species library
\ecorisk\species.lib
Species radius library
\ecorisk\radius.lib
The next step is to select all of species of interest and the species needed to complete the food web.
Available
Periphyton
Phytoplankton
Racoon
Reed canarygrass
Rainbow trout (adults)
Rainbow trout (eggs)
Rainbow trout (juvenile)
Rushes
Salmon (adults)
Salmon (eggs)
Salmon (juvenile)
Smallmouth bass
Terrestrial arthropods
Tule
Weasel
Water milfoil
Woodhouse's toad (adult)
Woodhouse's toad (tadpole)
Western aquatic garter sna
White sturgeon
Add>>
<<Remove
Selected
American coot
American kestrel
American white pelican
Beaver
Black cottonwood
Bald eagle
Bufflehead
Canada goose
Carp
Channel catfish
Clams
Cliff swallow
Common snipe
Coyote
Columbia pebblesnail
California quail
Crayfish
Columbia yellowcress
Daphnia magna
Dense sedge

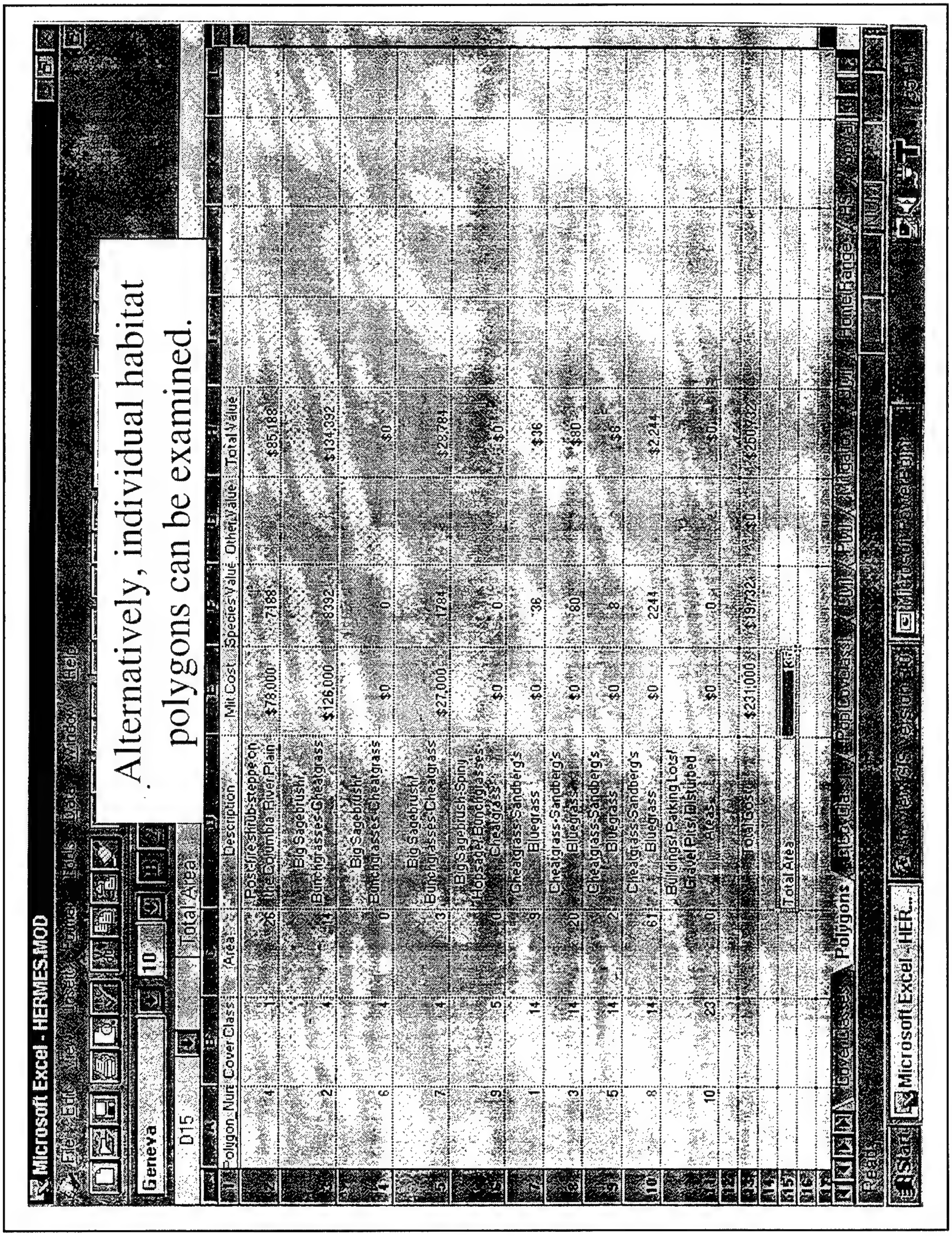

ArcView GIS Version 3.0
Hanford Site
The user can then visually examine the distribution of each habitat type.
ArcView GIS Version 3...
Microsoft PowerPoint


ArcView GIS Version 3.0
Hanford Site
Cover Areas
HERMES then calculates the area of each habitat polygon within the selected area(s) and determines the habitat type for each polygon.
ArcView GIS Version 3...


ArcView GIS Version 3.0
File Edit View Theme Analysis Graphics Window Help
Hanford Site
Roads
Rivers
Hsbound
Areas
Habitat
Repeat for as many different impact locations as desired.
1
2
3
Start
Microsoft Excel HERM
ArcView GIS Version 3...
Microsoft PowerPoint


Microsoft Excel - HERMES.MOD
Geneva
10
C11
Custom
100%
Cover Class
Area
Description
Mit Cost
Species Value
Other Value
Total Value
Data are fed to the spreadsheet portion of the model for detailed analysis of habitat replacement costs and ecological values.
Cover Classes
Microsoft Excel
Start


HERMES calculates total values and values for each habitat type.
Habitat Replacement Cost
Ecological Value
Microsoft Excel - HERMES.MOD
Cover Class
Area
Description
Mit Cost
Species Value
Other Value
Total Value
Post-fire shrub-steppe on the Columbia River Plain
$78,000
7188
$85,188
Big Sagebrush/ Bunchgrasses-Cheatgrass
$153,000
10176
$163,176
Big Sagebrush-Spiny Hopsage/ Bunchgrasses-Cheatgrass
Cheatgrass-Sandberg's Bluegrass
2368
$2,368
Buildings/ Parking Lots/ Gravel Pits/ Disturbed Areas
Total Cost
$231,000
$19,732
$0
$250,732


Microsoft Excel - HERMES.MOD
Alternatively, individual habitat polygons can be examined.
Polygon Num
Cover Class
Area
Description
Mit Cost
Species Value
Other Value
Total Value
Total Costs
Total Area
Polygons
Microsoft Excel - HER...

Mitigation / Habitat Replacement

- Based on user-defined values table
- User determines if habitat type is mitigable
- User defines mitigation thresholds (minimum area that would require compensation)
- Costs of different revegetation components are defined
- Can be altered for "what-if" analyses

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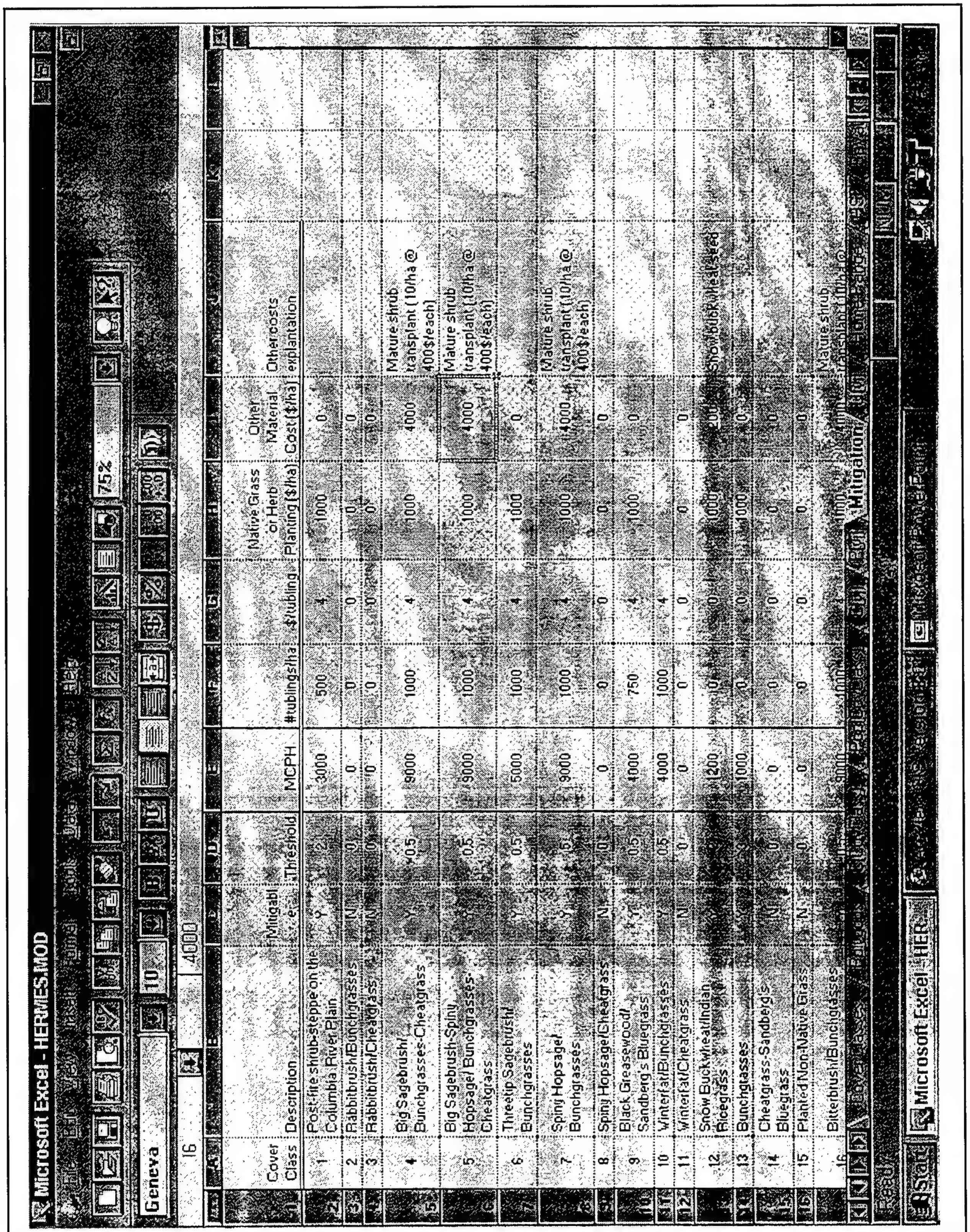
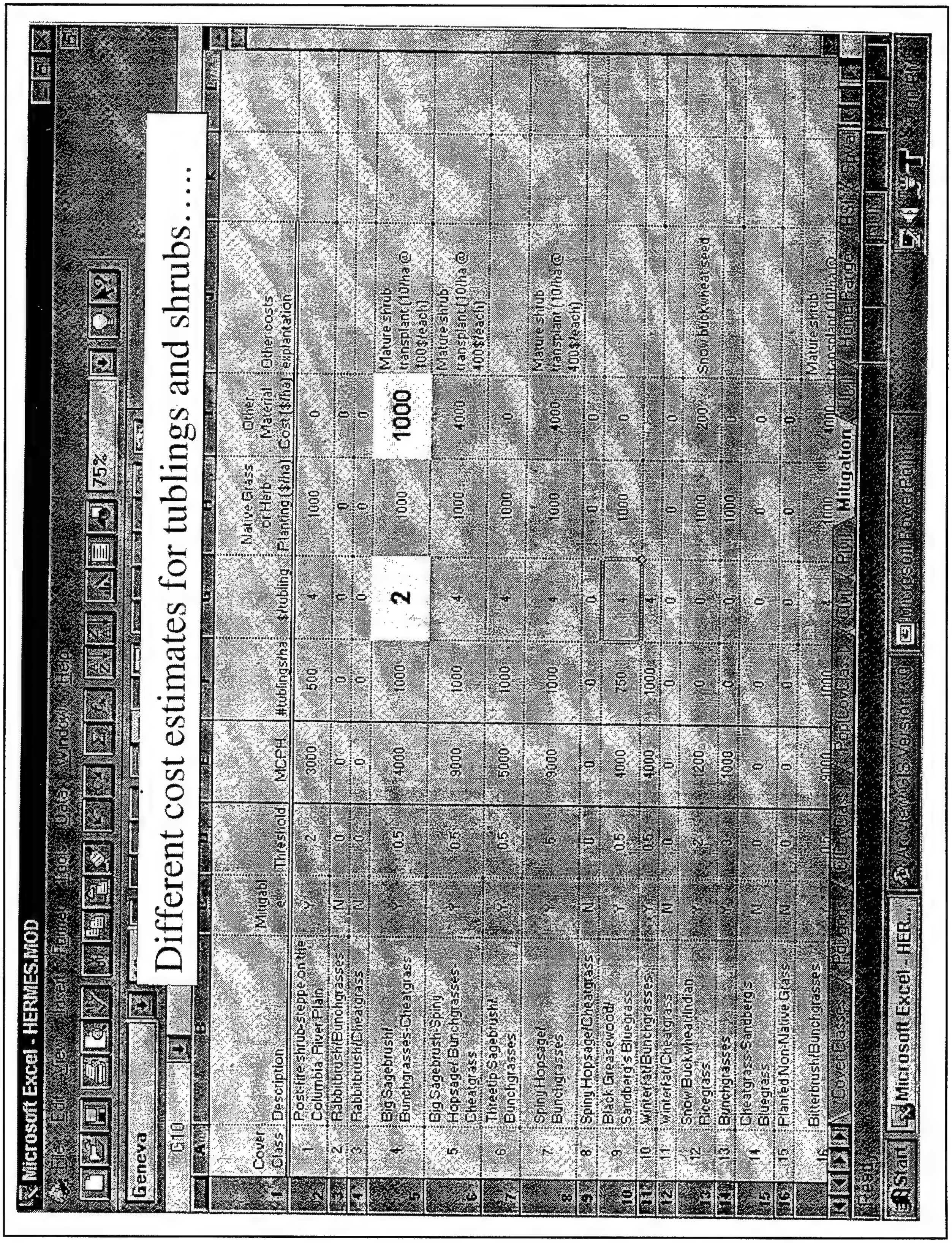
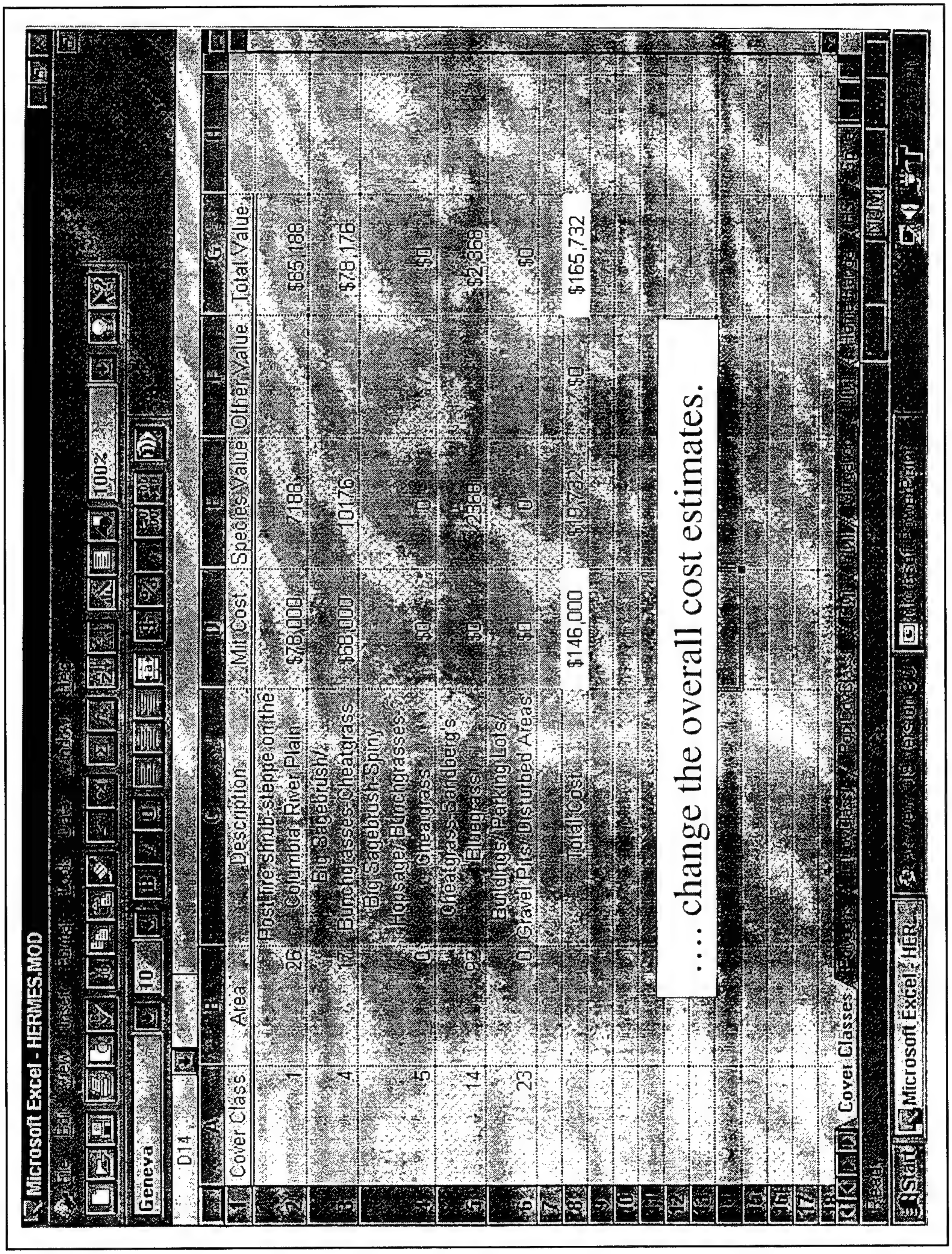
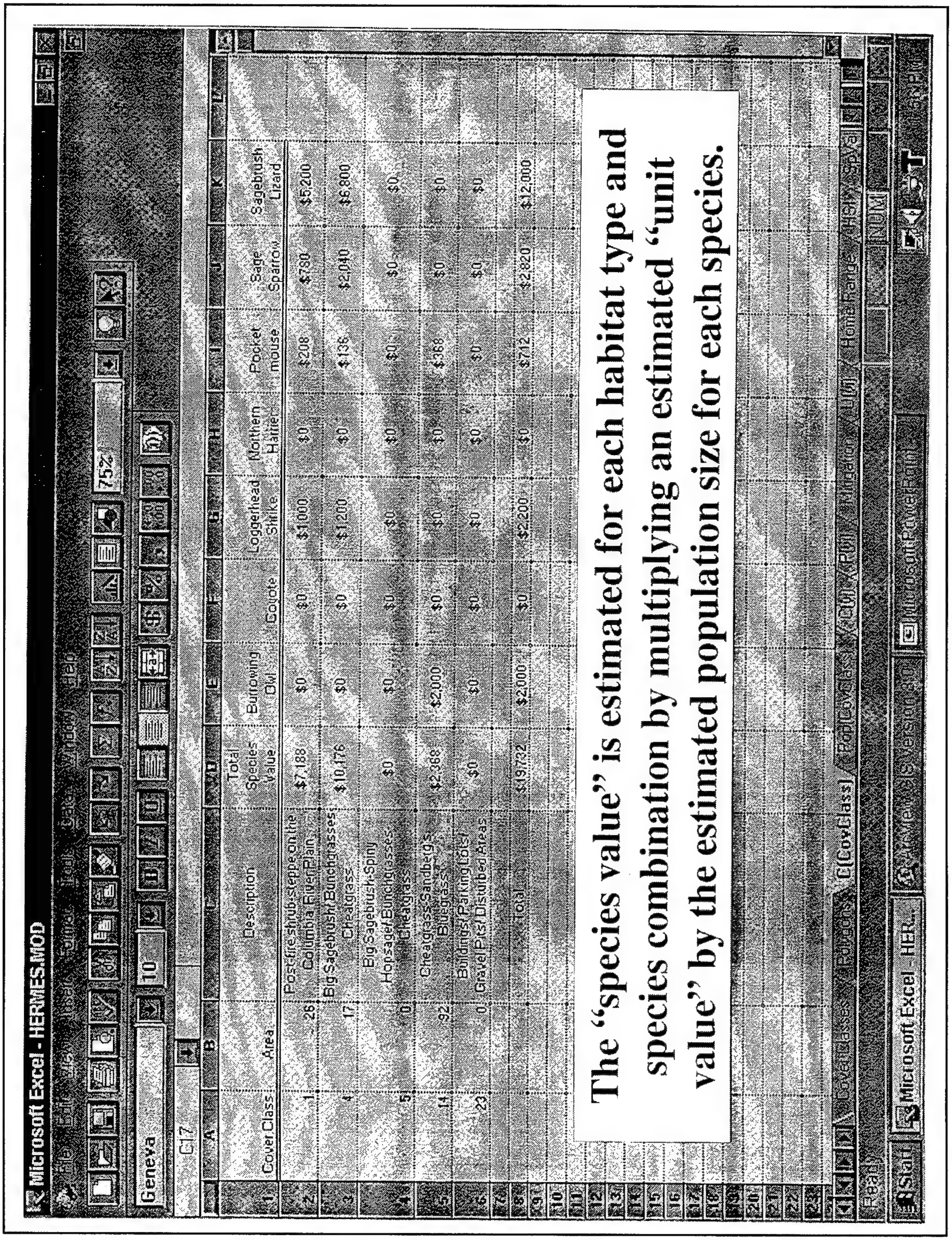


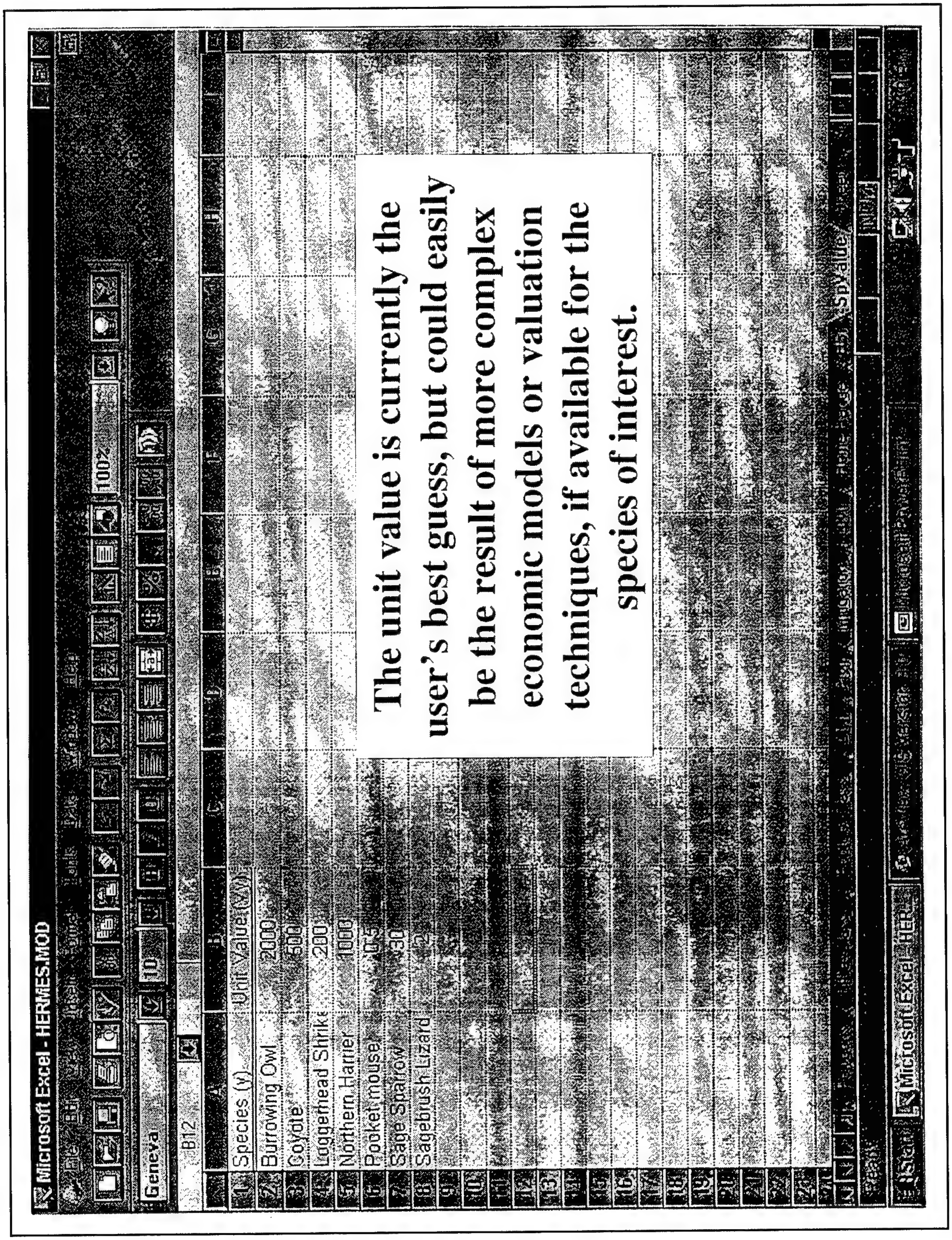
Cover Class	Description	Mitigable	Threshold	MCPH	#tublings/ha	$/tubling	Native Grass or Herb Planting ($/ha)	Other Material Cost ($/ha)	Other costs explantation
1	Post-fire shrub-steppe on the Columbia River Plain	Y	2	3000	500	4	1000	0	
2	Rabbitbrush/Bunchgrasses	N	0	0	0	0	0	0	
3	Rabbitbrush/Cheatgrass	N	0	0	0	0	0	0	
4	Big Sagebrush/ Bunchgrasses-Cheatgrass	Y	0.5	9000	1000	4	1000	4000	Mature shrub transplant (10/ha @ 400$/each)
5	Big Sagebrush-Spiny Hopsage/ Bunchgrasses-Cheatgrass	Y	0.5	9000	1000	4	1000	4000	Mature shrub transplant (10/ha @ 400$/each)
6	Threetip Sagebrush/ Bunchgrasses	Y	0.5	5000	1000	4	1000	0	
7	Spiny Hopsage/ Bunchgrasses	Y	[illegible]	9000	1000	4	1000	4000	Mature shrub transplant (10/ha @ 400$/each)
8	Spiny Hopsage/Cheatgrass	N	0	0	0	0	0	0	
9	Black Greasewood/ Sandberg's Bluegrass	Y	0.5	4000	750	4	1000	0	
10	Winterfat/Bunchgrasses	Y	0.5	4000	1000	4			
11	Winterfat/Cheatgrass	N	0	0	0	0	0	0	
12	Snow Buckwheat/Indian Ricegrass	[illegible]	[illegible]	1200	10	0	1000	200	Snow buckwheat seed
13	Bunchgrasses	Y	[illegible]	1000	0	0	1000	0	
14	Cheatgrass-Sandberg's Bluegrass	N	0	0	0	0	0	0	
15	Planted Non-Native Grass	N	0	0	0	0	0	0	
16	Bitterbrush/Bunchgrasses	[illegible]	[illegible]	9000	1000	[illegible]	1000	4000	Mature shrub transplant (10/ha @


Microsoft Excel - HERMES.MOD
Different cost estimates for tublings and shrubs.....
Cover Class
Description
Mitigable
Threshold
MCPH
#tublings/ha
$/tubling
Native Grass or Herb Planting ($/ha)
Other Material Cost ($/ha)
Other costs explanation
Mitigation

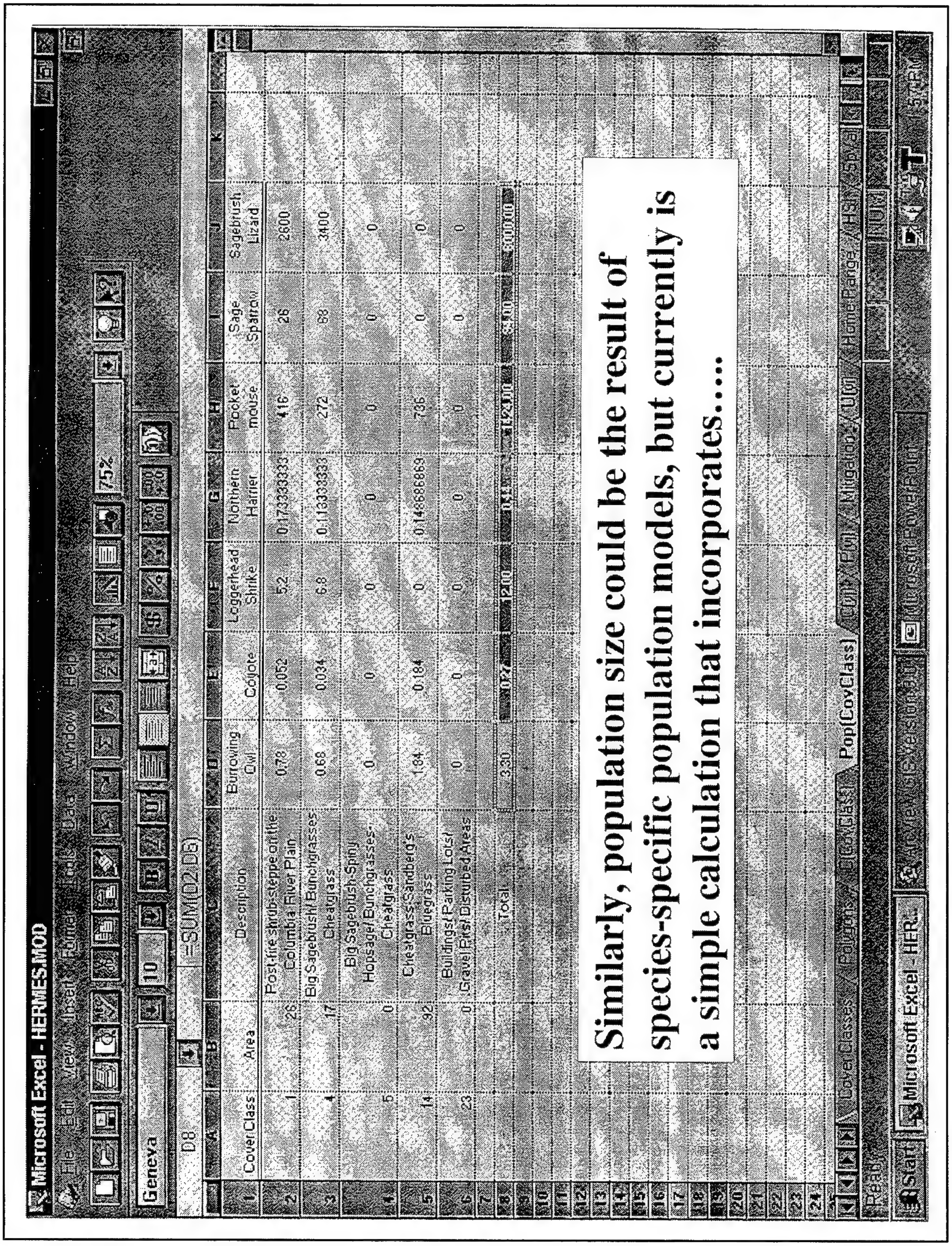

Microsoft Excel - HERMES.MOD
Geneva
10
100%
D14
Cover Class
Area
Description
Mit Cost
Species Value
Other Value
Total Value
1
26
Postfire shrub-steppe on the Columbia River Plain
$78,000
7188
$85,188
4
17
Big Sagebrush/ Bunchgrasses-Cheatgrass
$68,000
10176
$78,176
5
0
Big Sagebrush-Spiny Hopsage/ Bunchgrasses-Cheatgrass
$0
0
$0
14
Cheatgrass-Sandberg's Bluegrass
$0
2368
$2,368
23
0
Buildings/ Parking Lots/ Gravel Pits/ Disturbed Areas
$0
0
$0
Total Cost
$146,000
$19,732
$0
$165,732
.... change the overall cost estimates.
Cover Classes
Start
Microsoft Excel - HER...

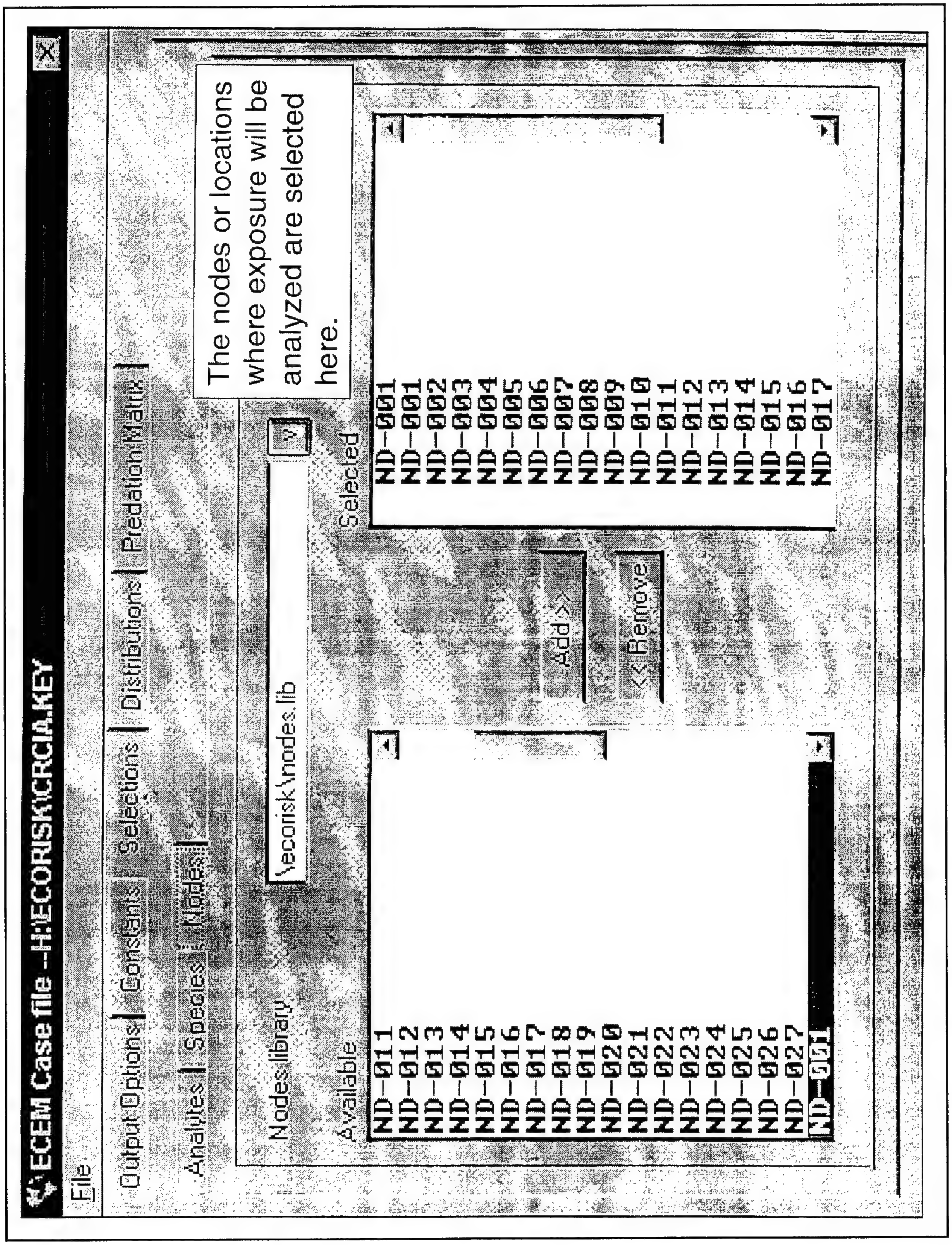


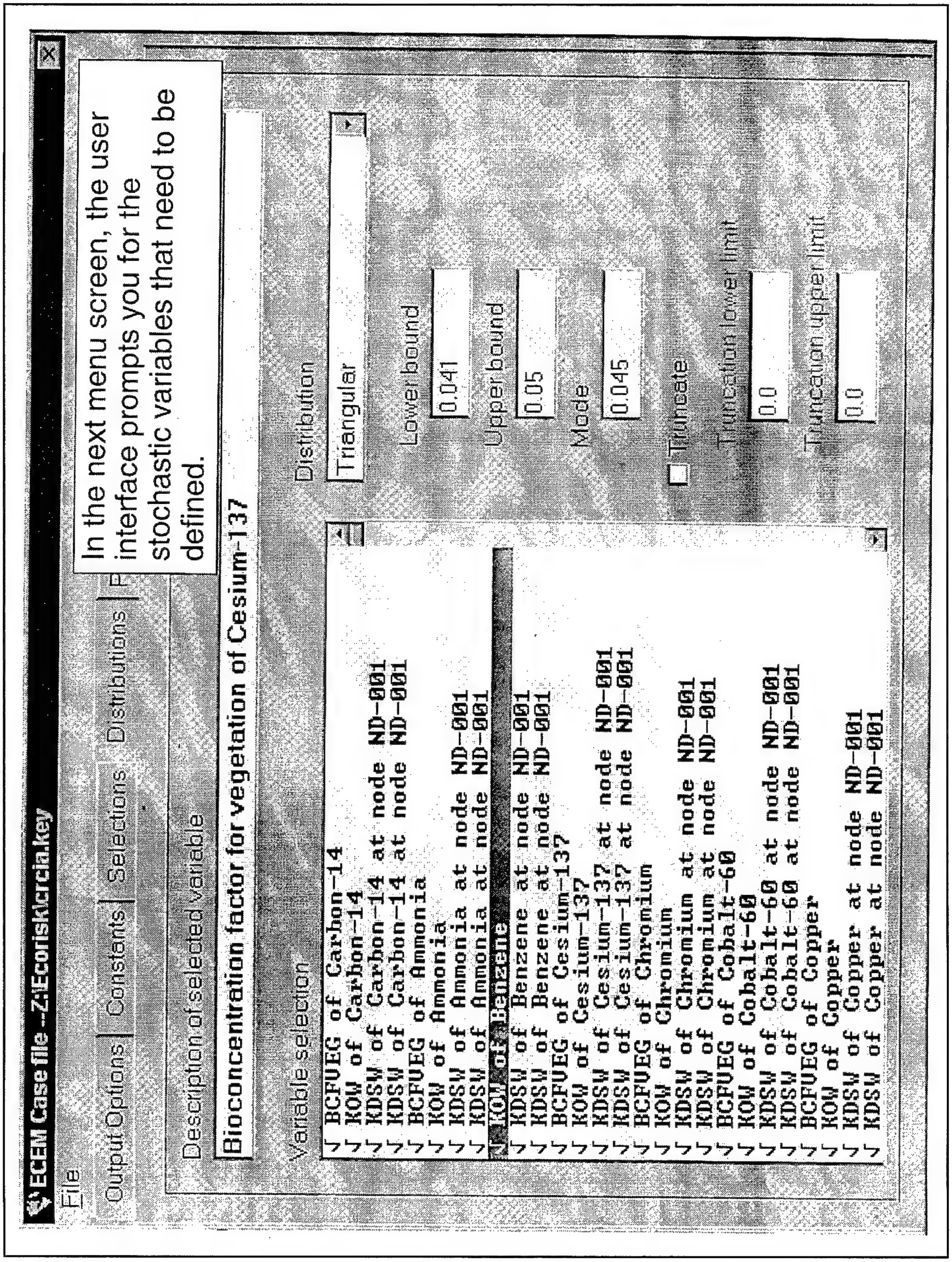
Cover Class	Area	Description	Total Species Value	Burrowing Owl	Coyote	Loggerhead Shrike	Northern Harrier	Pocket mouse	Sage Sparrow	Sagebrush Lizard
1	26	Post-fire shrub-steppe on the Columbia River Plain	$7,188	$0	$0	$1000	$0	$208	$780	$5,200
4	17	Big Sagebrush/Bunchgrasses/Cheatgrass	$10,176	$0	$0	$1,200	$0	$136	$2,040	$6,800
5	0	Big Sagebrush-Spiny Hopsage/Bunchgrasses-Cheatgrass	$0	$0	$0	$0	$0	$0	$0	$0
14	92	Cheatgrass-Sandberg's Bluegrass	$2,368	$2,000	$0	$0	$0	$368	$0	$0
23	0	Buildings/Parking Lots/Gravel Pits/Disturbed Areas	$0	$0	$0	$0	$0	$0	$0	$0
		Total	$19,732	$2,000	$0	$2,200	$0	$712	$2,820	$12,000

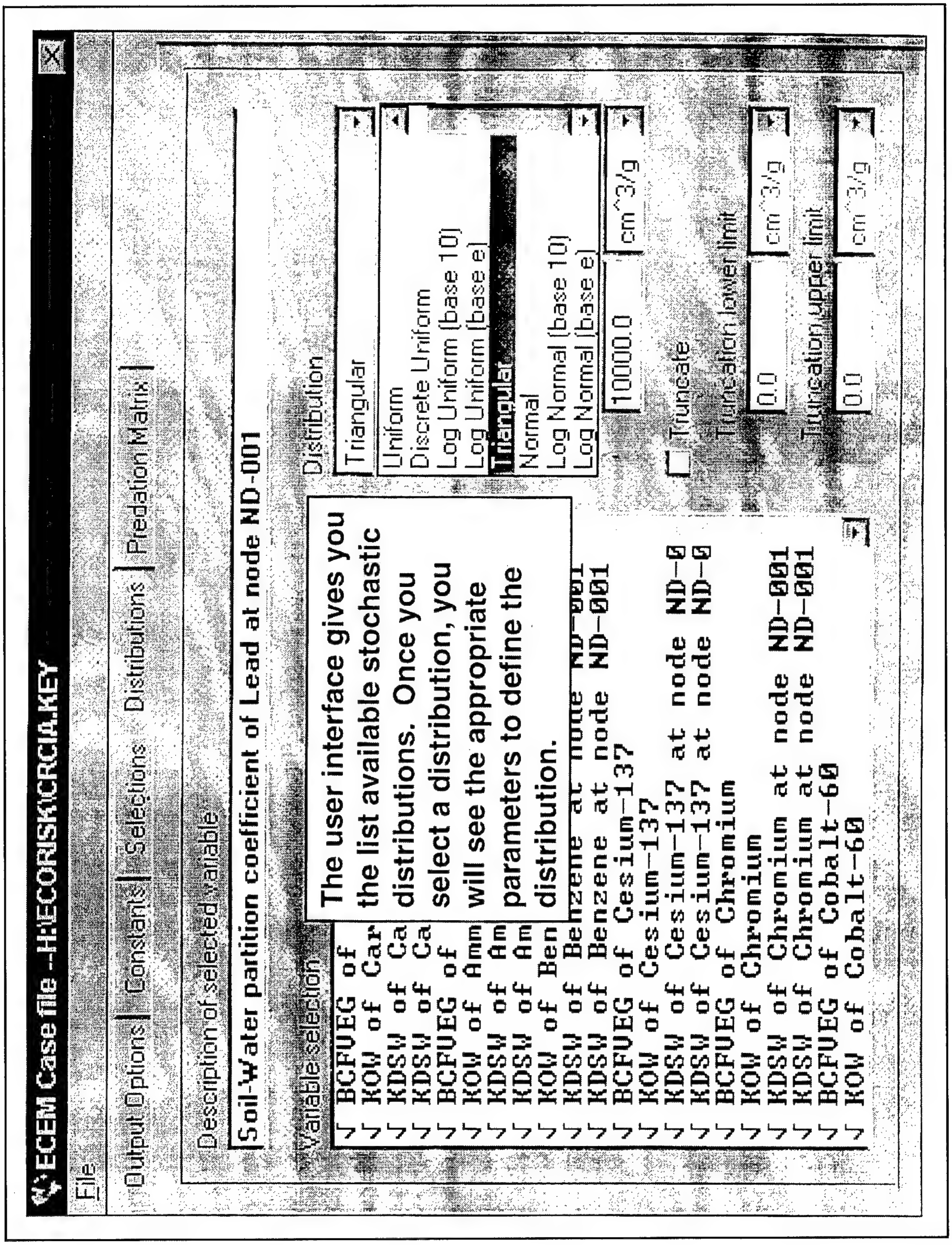


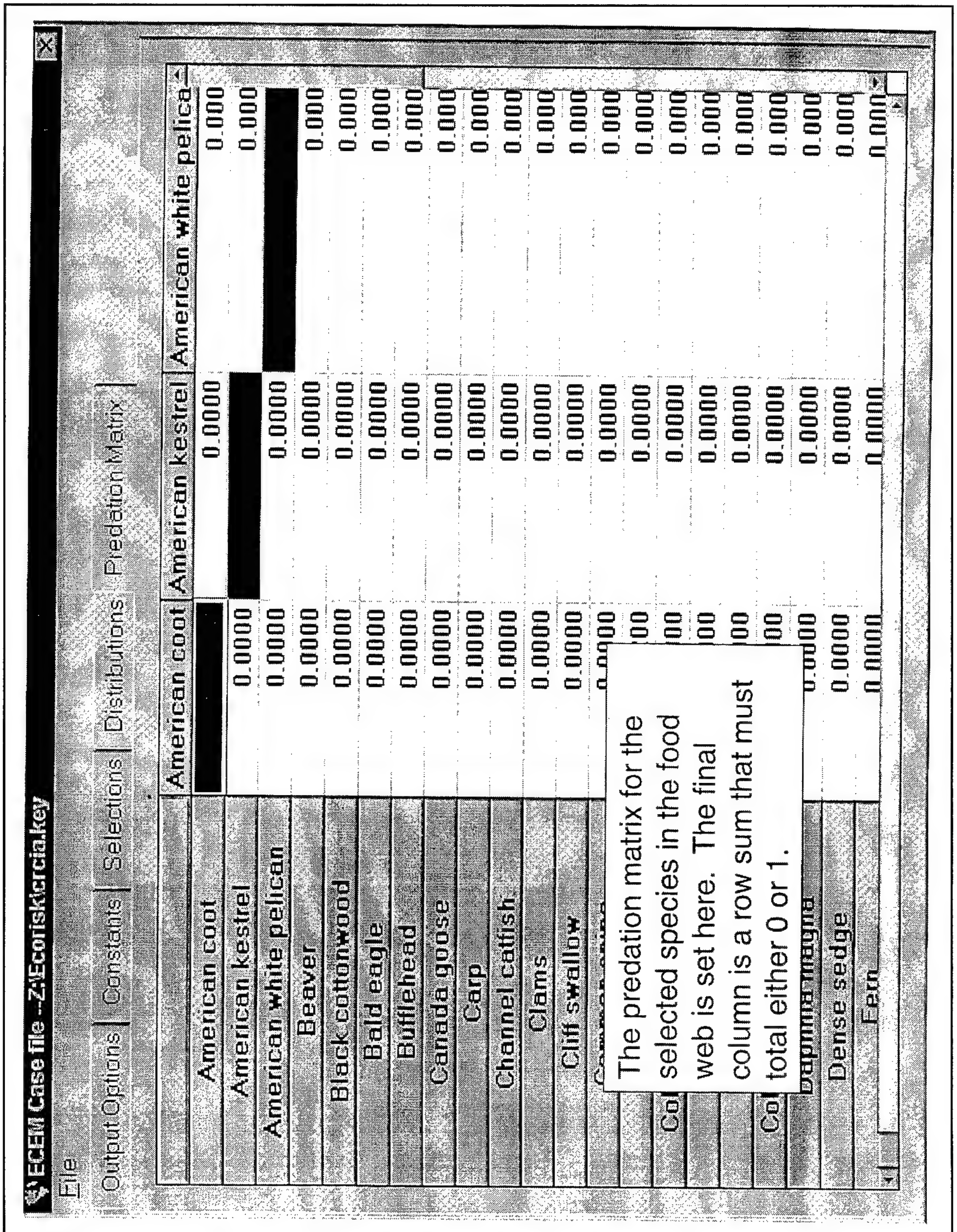
Microsoft Excel - HERMES.MOD
Species (y)
Burrowing Owl
Coyote
Loggerhead Shrike
Northern Harrier
Pocket mouse
Sage Sparrow
Sagebrush Lizard
The unit value is currently the user's best guess, but could easily be the result of more complex economic models or valuation techniques, if available for the species of interest.

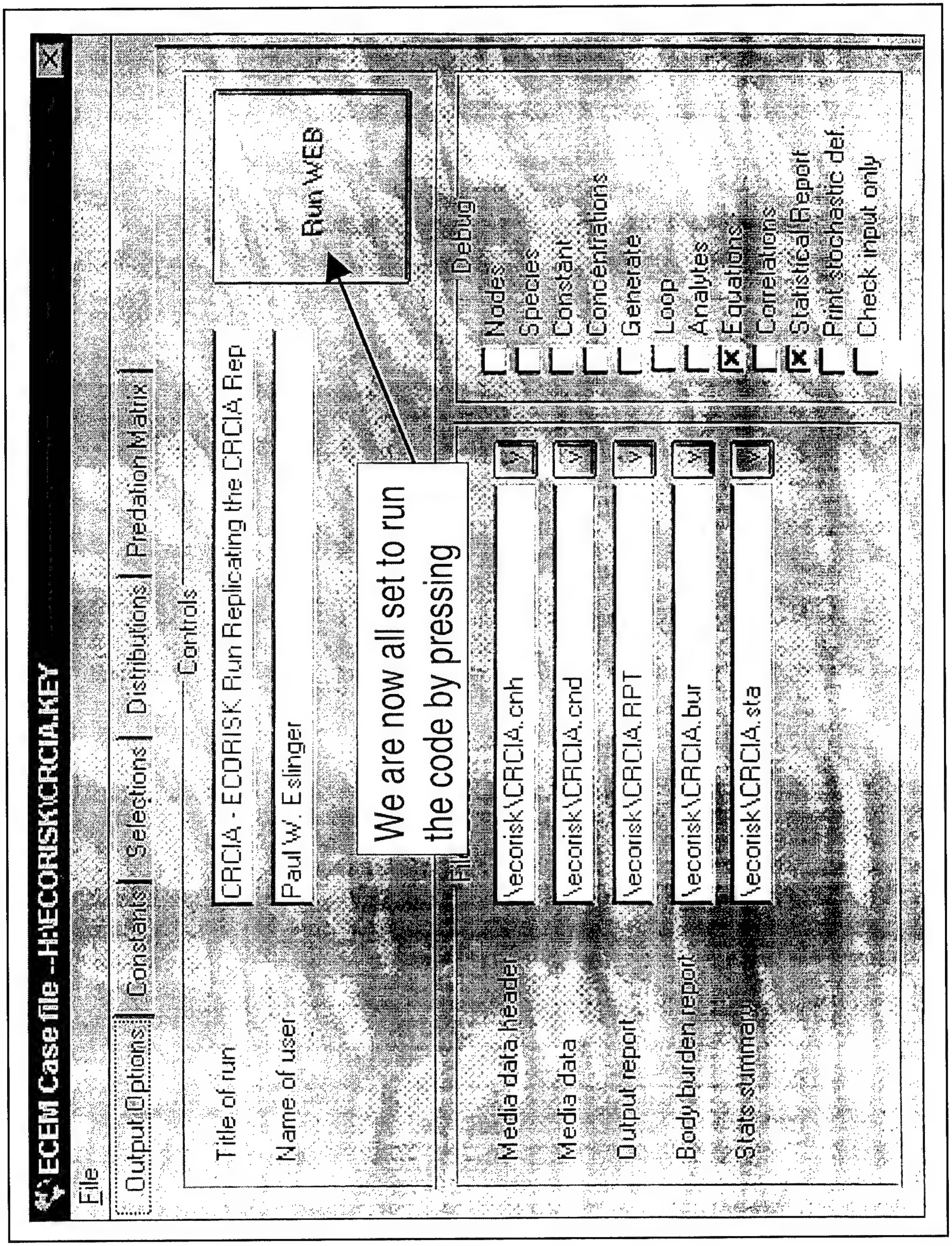

Microsoft Excel - HERMES.MOD
Similarly, population size could be the result of
species-specific population models, but currently is
a simple calculation that incorporates.....


ECEM Case file --H:\ECORISK\CRCIA.KEY
File
Output Options
Constants
Selections
Distributions
PredationMatrix
Analytes
Species
Nodes
Nodes library
\ecorisk\nodes.lib
Available
ND-011
ND-012
ND-013
ND-014
ND-015
ND-016
ND-017
ND-018
ND-019
ND-020
ND-021
ND-022
ND-023
ND-024
ND-025
ND-026
ND-027
ND-001
Add >>
<< Remove
Selected
ND-001
ND-001
ND-002
ND-003
ND-004
ND-005
ND-006
ND-007
ND-008
ND-009
ND-010
ND-011
ND-012
ND-013
ND-014
ND-015
ND-016
ND-017
The nodes or locations where exposure will be analyzed are selected here.

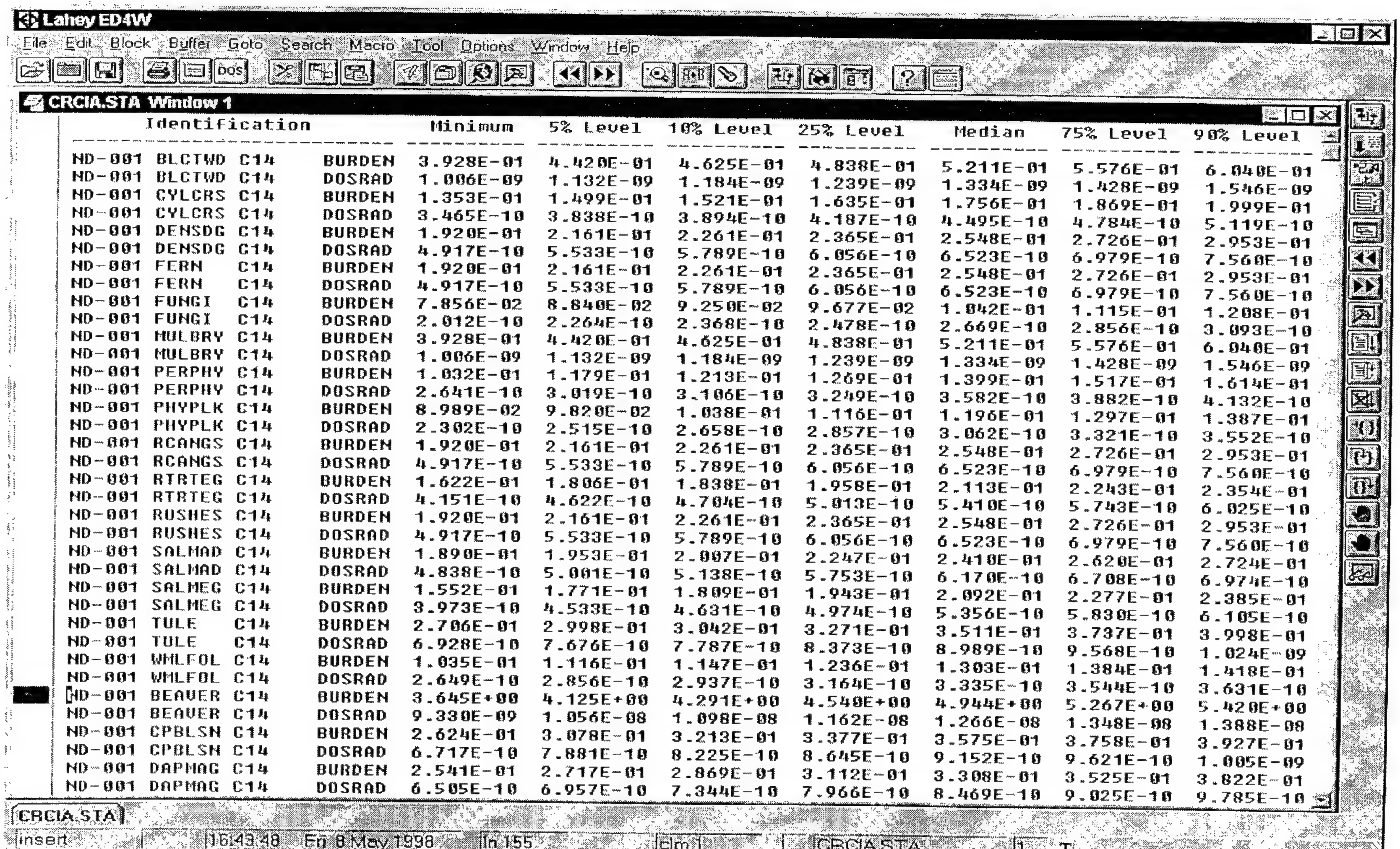

ECEM Case file --Z:\Ecorisk\crcia.key
File
Output Options
Constants
Selections
Distributions
In the next menu screen, the user interface prompts you for the stochastic variables that need to be defined.
Description of selected variable
Bioconcentration factor for vegetation of Cesium-137
Variable selection
BCFVEG of Carbon-14
KOW of Carbon-14
KDSW of Carbon-14 at node ND-001
KDSW of Carbon-14 at node ND-001
BCFVEG of Ammonia
KOW of Ammonia
KDSW of Ammonia at node ND-001
KDSW of Ammonia at node ND-001
KOW of Benzene
KDSW of Benzene at node ND-001
KDSW of Benzene at node ND-001
BCFVEG of Cesium-137
KOW of Cesium-137
KDSW of Cesium-137 at node ND-001
KDSW of Cesium-137 at node ND-001
BCFVEG of Chromium
KOW of Chromium
KDSW of Chromium at node ND-001
KDSW of Chromium at node ND-001
BCFVEG of Cobalt-60
KOW of Cobalt-60
KDSW of Cobalt-60 at node ND-001
KDSW of Cobalt-60 at node ND-001
BCFVEG of Copper
KOW of Copper
KDSW of Copper at node ND-001
KDSW of Copper at node ND-001
Distribution
Triangular
Lower bound
0.041
Upper bound
0.05
Mode
0.045
Truncate
Truncation lower limit
0.0
Truncation upper limit
0.0


ECEM Case file --H:\ECORISK\CRCIA.KEY
File
Output Options
Constants
Selections
Distributions
Predation Matrix
Description of selected variable
Soil-Water partition coefficient of Lead at node ND-001
Variable selection
Distribution
Triangular
Uniform
Discrete Uniform
Log Uniform (base 10)
Log Uniform (base e)
Triangular
Normal
Log Normal (base 10)
Log Normal (base e)
10000.0
cm^3/g
Truncate
Truncation lower limit
0.0
cm^3/g
Truncation upper limit
0.0
cm^3/g
The user interface gives you the list available stochastic distributions. Once you select a distribution, you will see the appropriate parameters to define the distribution.


File
Output Options
Constants
Selections
Distributions
Predation Matrix
American coot
American kestrel
American white pelica
American coot
American kestrel
American white pelican
Beaver
Black cottonwood
Bald eagle
Bufflehead
Canada goose
Carp
Channel catfish
Clams
Cliff swallow
Dense sedge
Fern
The predation matrix for the selected species in the food web is set here. The final column is a row sum that must total either 0 or 1.


ECEM Case file --H:\ECORISK\CRCIA.KEY
File
Output Options
Constants
Selections
Distributions
Predation Matrix
Controls
Title of run
CRCIA - ECORISK Run Replicating the CRCIA Rep
Name of user
Paul W. Eslinger
Run WEB
We are now all set to run the code by pressing
Media data header
\ecorisk\CRCIA.cnh
Media data
\ecorisk\CRCIA.cnd
Output report
\ecorisk\CRCIA.RPT
Body burden report
\ecorisk\CRCIA.bur
Stats summary
\ecorisk\CRCIA.sta
Debug
Nodes
Species
Constant
Concentrations
Generate
Loop
Analytes
Equations
Correlations
Statistical Report
Print stochastic def.
Check input only

What kind of results do you get from ECEM?



Identification				Minimum	5% Level	10% Level	25% Level	Median	75% Level	90% Level
ND-001	BLCTWD	C14	BURDEN	3.928E-01	4.420E-01	4.625E-01	4.838E-01	5.211E-01	5.576E-01	6.040E-01
ND-001	BLCTWD	C14	DOSRAD	1.006E-09	1.132E-09	1.184E-09	1.239E-09	1.334E-09	1.428E-09	1.546E-09
ND-001	CYLCRS	C14	BURDEN	1.353E-01	1.499E-01	1.521E-01	1.635E-01	1.756E-01	1.869E-01	1.999E-01
ND-001	CYLCRS	C14	DOSRAD	3.465E-10	3.838E-10	3.894E-10	4.187E-10	4.495E-10	4.784E-10	5.119E-10
ND-001	DENSDG	C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	DENSDG	C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	FERN	C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	FERN	C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	FUNGI	C14	BURDEN	7.856E-02	8.840E-02	9.250E-02	9.677E-02	1.042E-01	1.115E-01	1.208E-01
ND-001	FUNGI	C14	DOSRAD	2.012E-10	2.264E-10	2.368E-10	2.478E-10	2.669E-10	2.856E-10	3.093E-10
ND-001	MULBRY	C14	BURDEN	3.928E-01	4.420E-01	4.625E-01	4.838E-01	5.211E-01	5.576E-01	6.040E-01
ND-001	MULBRY	C14	DOSRAD	1.006E-09	1.132E-09	1.184E-09	1.239E-09	1.334E-09	1.428E-09	1.546E-09
ND-001	PERPHY	C14	BURDEN	1.032E-01	1.179E-01	1.213E-01	1.269E-01	1.399E-01	1.517E-01	1.614E-01
ND-001	PERPHY	C14	DOSRAD	2.641E-10	3.019E-10	3.106E-10	3.249E-10	3.582E-10	3.882E-10	4.132E-10
ND-001	PHYPLK	C14	BURDEN	8.989E-02	9.820E-02	1.038E-01	1.116E-01	1.196E-01	1.297E-01	1.387E-01
ND-001	PHYPLK	C14	DOSRAD	2.302E-10	2.515E-10	2.658E-10	2.857E-10	3.062E-10	3.321E-10	3.552E-10
ND-001	RCANGS	C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	RCANGS	C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	RTRTEG	C14	BURDEN	1.622E-01	1.806E-01	1.838E-01	1.958E-01	2.113E-01	2.243E-01	2.354E-01
ND-001	RTRTEG	C14	DOSRAD	4.151E-10	4.622E-10	4.704E-10	5.013E-10	5.410E-10	5.743E-10	6.025E-10
ND-001	RUSHES	C14	BURDEN	1.920E-01	2.161E-01	2.261E-01	2.365E-01	2.548E-01	2.726E-01	2.953E-01
ND-001	RUSHES	C14	DOSRAD	4.917E-10	5.533E-10	5.789E-10	6.056E-10	6.523E-10	6.979E-10	7.560E-10
ND-001	SALMAD	C14	BURDEN	1.890E-01	1.953E-01	2.007E-01	2.247E-01	2.410E-01	2.620E-01	2.724E-01
ND-001	SALMAD	C14	DOSRAD	4.838E-10	5.001E-10	5.138E-10	5.753E-10	6.170E-10	6.708E-10	6.974E-10
ND-001	SALMEG	C14	BURDEN	1.552E-01	1.771E-01	1.809E-01	1.943E-01	2.092E-01	2.277E-01	2.385E-01
ND-001	SALMEG	C14	DOSRAD	3.973E-10	4.533E-10	4.631E-10	4.974E-10	5.356E-10	5.830E-10	6.105E-10
ND-001	TULE	C14	BURDEN	2.706E-01	2.998E-01	3.042E-01	3.271E-01	3.511E-01	3.737E-01	3.998E-01
ND-001	TULE	C14	DOSRAD	6.928E-10	7.676E-10	7.787E-10	8.373E-10	8.989E-10	9.568E-10	1.024E-09
ND-001	WMLFOL	C14	BURDEN	1.035E-01	1.116E-01	1.147E-01	1.236E-01	1.303E-01	1.384E-01	1.418E-01
ND-001	WMLFOL	C14	DOSRAD	2.649E-10	2.856E-10	2.937E-10	3.164E-10	3.335E-10	3.544E-10	3.631E-10
ND-001	BEAVER	C14	BURDEN	3.645E+00	4.125E+00	4.291E+00	4.540E+00	4.944E+00	5.267E+00	5.420E+00
ND-001	BEAVER	C14	DOSRAD	9.330E-09	1.056E-08	1.098E-08	1.162E-08	1.266E-08	1.348E-08	1.388E-08
ND-001	CPBLSN	C14	BURDEN	2.624E-01	3.078E-01	3.213E-01	3.377E-01	3.575E-01	3.758E-01	3.927E-01
ND-001	CPBLSN	C14	DOSRAD	6.717E-10	7.881E-10	8.225E-10	8.645E-10	9.152E-10	9.621E-10	1.005E-09
ND-001	DAPMAG	C14	BURDEN	2.541E-01	2.717E-01	2.869E-01	3.112E-01	3.308E-01	3.525E-01	3.822E-01
ND-001	DAPMAG	C14	DOSRAD	6.505E-10	6.957E-10	7.344E-10	7.966E-10	8.469E-10	9.025E-10	9.785E-10

System Requirements for ECEM

- Software
  - Windows Application
  - Visual Basic User Interface
  - Fortran 90 Code
- Hardware
  - PC running Windows 95
  - 40 MB RAM
  - 150 MB Disk Space

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For more information contact:

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Richland, WA 99352
(509) 376-5345
charles.brandt@pnl.gov

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"HERMES"

Health and Ecological Risk Management and Evaluation System

An Integrated Environmental
Decision Support Tool

Battelle

Developed by Pacific Northwest National Laboratory for the U. S. Department of Energy

For information contact:

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P.O. Box 999 MSIN K6-84
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michael.sackschewsky@pnl.gov

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Background

- Need to evaluate ecological and monetary trade-offs on the Hanford Site between remediation, restoration, and land use options before action is taken
- Ecological risk assessments normally focus on contaminant effects on wildlife, ignore impacts of the remediation action itself
- Need to connect different decision dimensions using common units

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Objectives

- Develop a GIS-based decision support tool that concisely describes the current environmental landscape and can be used to make decisions
- Develop a tool that provides ecological information in a format directly comparable to other decision dimensions—including project costs and human health and wildlife risks

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Environmental Decision Making Made Easier

- HERMES—a flexible visualization and analysis program—helps environmental restoration, land use, and resource managers make decisions
- HERMES allows interactive evaluation of impacts with user-selected restoration costs and species values
- Other decision dimensions, such as human health, eco-risk, and ecosystem function can be included as extensions to the model

Battelle

Advantages

- Usable - links with user's existing databases
- Portable - can run on a laptop computer, which facilitates public involvement
- Easily manipulated - user can control data input values
- Expandable - modular design allows inclusion of additional decision dimensions

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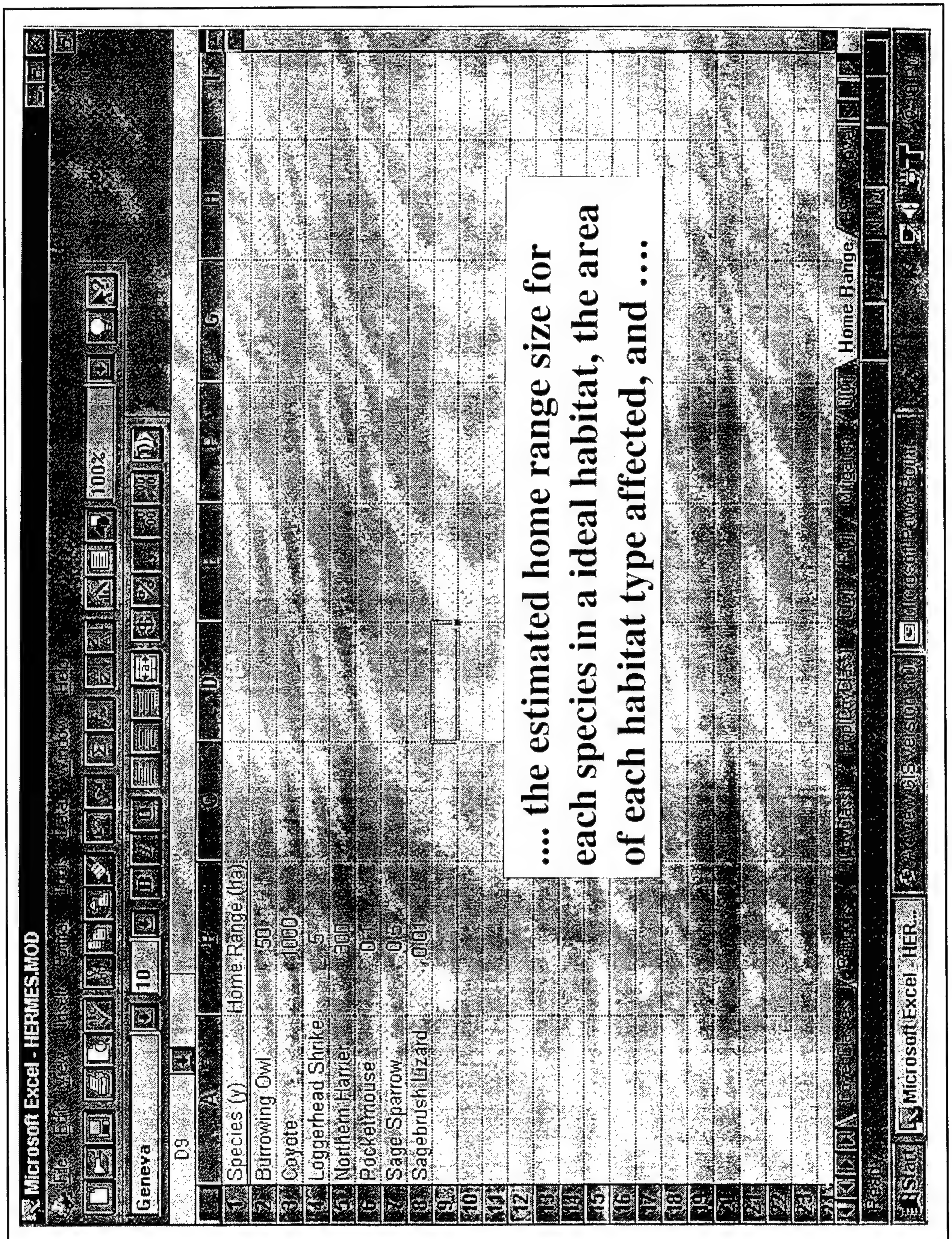

Microsoft Excel - HERMES.MOD
Species (y)
Home Range (ha)
Burrowing Owl
Coyote
1000
Loggerhead Shrike
Northern Harrier
Pocketmouse
Sage Sparrow
Sagebrush Lizard
.... the estimated home range size for
each species in a ideal habitat, the area
of each habitat type affected, and ....
Home Range
Microsoft Excel - HER...

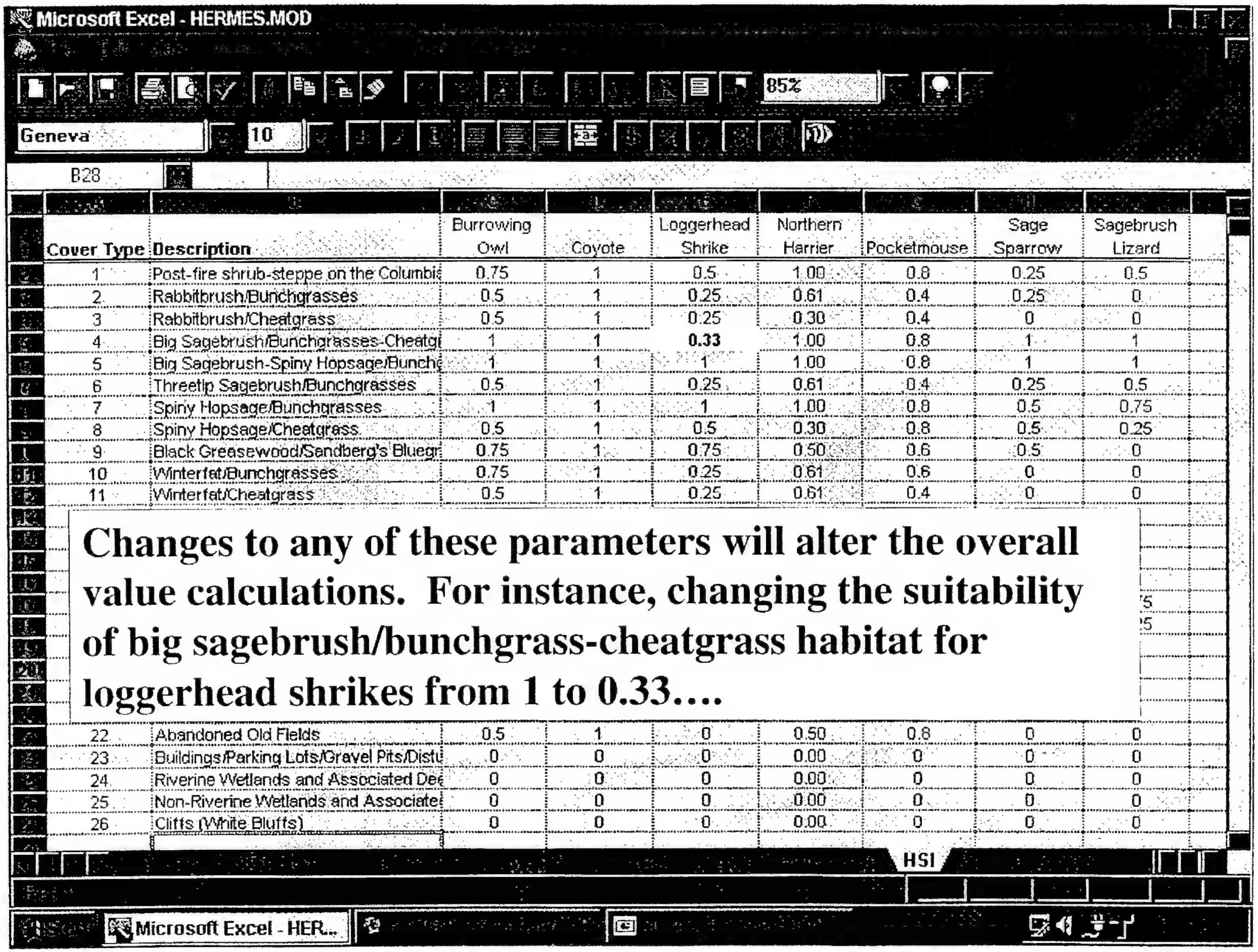
Microsoft Excel - HERMES.MOD

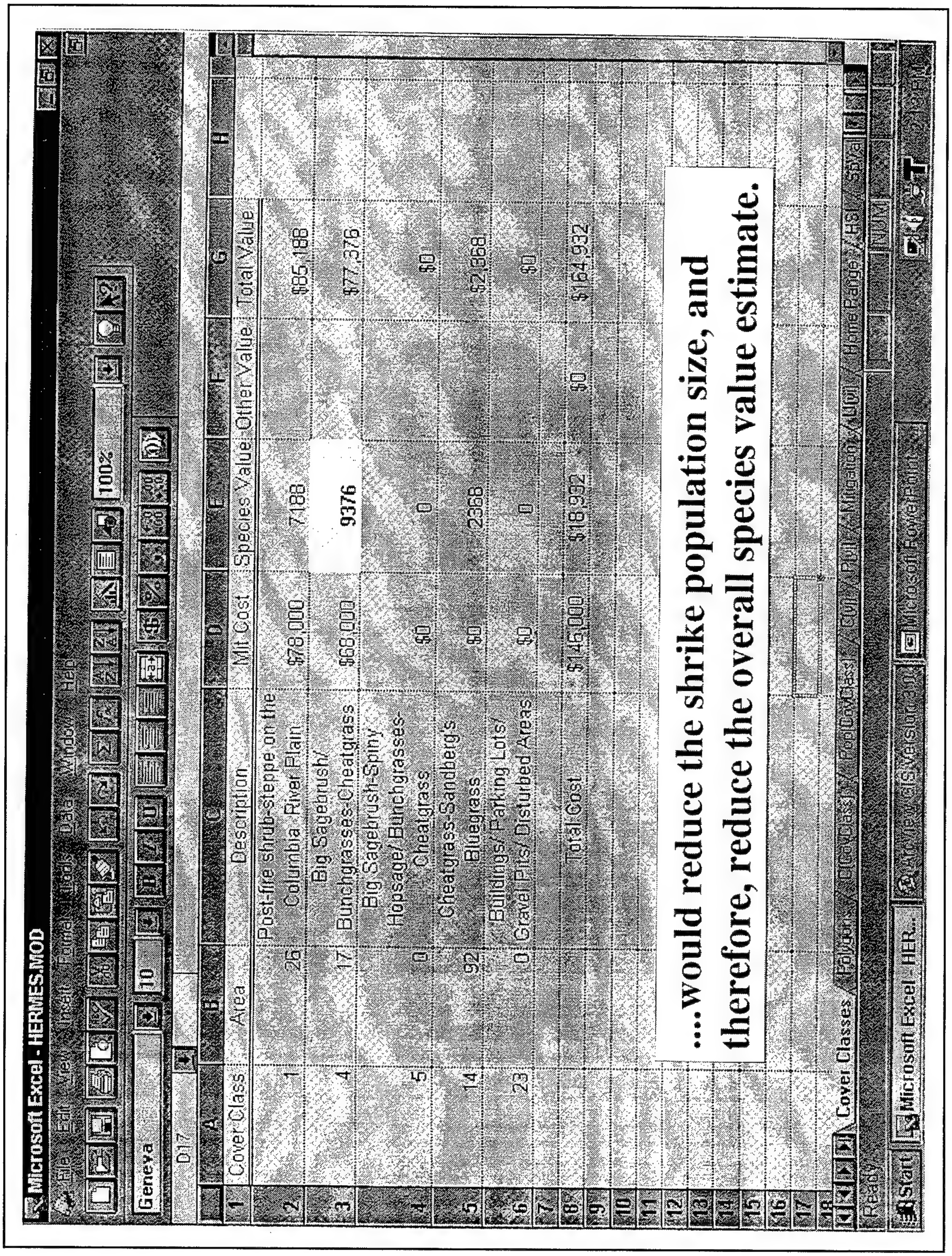
.... the estimated suitability of each habitat type for each species.

Cover Type	Description	Burrowing Owl	Coyote	Loggerhead Shrike	Northern Harrier	Pocketmouse	Sage Sparrow	Sagebrush Lizard
1	Post-fire shrub-steppe on the Columbi	0.75	1	0.5	1.00	0.8	0.25	0.5
2	Rabbitbrush/Bunchgrasses	0.5	1	0.25	0.61	0.4	0.25	0
3	Rabbitbrush/Cheatgrass	0.5	1	0.25	0.30	0.4	0	0
4	Big Sagebrush/Bunchgrasses-Cheatg	1	1	1	1.00	0.8	1	1
5	Big Sagebrush-Spiny Hopsage/Bunch	1	1	1	1.00	0.8	1	1
6	Threetip Sagebrush/Bunchgrasses	0.5	1	0.25	0.61	0.4	0.25	0.5
7	Spiny Hopsage/Bunchgrasses	1	1	1	1.00	0.8	0.5	0.75
8	Spiny Hopsage/Cheatgrass	0.5	1	0.5	0.30	0.8	0.5	0.25
9	Black Greasewood/Sandberg's Blueg	0.75	1	0.75	0.50	0.6	0.5	0
10	Winterfat/Bunchgrasses	0.75	1	0.25	0.61	0.6	0	0
11	Winterfat/Cheatgrass	0.5	1	0.25	0.61	0.4	0	0
12	Snow Buckwheat/Indian Ricegrass	1	1	0.25	0.61	0.8	0	0
13	Bunchgrasses	0.75	1	0.25	0.30	0.6	0	0
14	Cheatgrass-Sandberg's Bluegrass	0.5	1	0	0.24	0.4	0	0
15	Planted Non-Native Grass	0.25	1	0	0.24	0.4	0	0
16	Bitterbrush/Bunchgrasses Sand Dune	0.5	1	0.75	1.00	0.8	0.5	0.75
17	Bitterbrush/Cheatgrass	0.5	1	0.5	0.50	0.8	0.25	0.25
18	Alkali Saltgrass-Cheatgrass	0.25	1	0	0.50	0.4	0	0
19	Riparian	0.5	1	0	0.61	1	0	0
20	Basalt Outcrops	0.25	1	0	0.61	0.2	0	0
21	Agricultural Areas	0.5	1	0	0.50	0.4	0	0
22	Abandoned Old Fields	0.5	1	0	0.50	0.8	0	0
23	Buildings/Parking Lots/Gravel Pits/Dist	0	0	0	0.00	0	0	0
24	Riverine Wetlands and Associated De	0	0	0	0.00	0	0	0
25	Non-Riverine Wetlands and Associate	0	0	0	0.00	0	0	0
26	Cliffs (White Bluffs)	0	0	0	0.00	0	0	0

HSI

Microsoft Excel - HER...


Microsoft Excel - HERMES.MOD
Geneva
10
85%
B28
Cover Type | Description | Burrowing Owl | Coyote | Loggerhead Shrike | Northern Harrier | Pocketmouse | Sage Sparrow | Sagebrush Lizard
1 | Post-fire shrub-steppe on the Columbi | 0.75 | 1 | 0.5 | 1.00 | 0.8 | 0.25 | 0.5
2 | Rabbitbrush/Bunchgrasses | 0.5 | 1 | 0.25 | 0.61 | 0.4 | 0.25 | 0
3 | Rabbitbrush/Cheatgrass | 0.5 | 1 | 0.25 | 0.30 | 0.4 | 0 | 0
4 | Big Sagebrush/Bunchgrasses-Cheatg | 1 | 1 | 0.33 | 1.00 | 0.8 | 1 | 1
5 | Big Sagebrush-Spiny Hopsage/Bunch | 1 | 1 | 1 | 1.00 | 0.8 | 1 | 1
6 | Threetip Sagebrush/Bunchgrasses | 0.5 | 1 | 0.25 | 0.61 | 0.4 | 0.25 | 0.5
7 | Spiny Hopsage/Bunchgrasses | 1 | 1 | 1 | 1.00 | 0.8 | 0.5 | 0.75
8 | Spiny Hopsage/Cheatgrass | 0.5 | 1 | 0.5 | 0.30 | 0.8 | 0.5 | 0.25
9 | Black Greasewood/Sandberg's Bluegr | 0.75 | 1 | 0.75 | 0.50 | 0.6 | 0.5 | 0
10 | Winterfat/Bunchgrasses | 0.75 | 1 | 0.25 | 0.61 | 0.6 | 0 | 0
11 | Winterfat/Cheatgrass | 0.5 | 1 | 0.25 | 0.61 | 0.4 | 0 | 0
Changes to any of these parameters will alter the overall value calculations. For instance, changing the suitability of big sagebrush/bunchgrass-cheatgrass habitat for loggerhead shrikes from 1 to 0.33….
22 | Abandoned Old Fields | 0.5 | 1 | 0 | 0.50 | 0.8 | 0 | 0
23 | Buildings/Parking Lots/Gravel Pits/Distu | 0 | 0 | 0 | 0.00 | 0 | 0 | 0
24 | Riverine Wetlands and Associated Dee | 0 | 0 | 0 | 0.00 | 0 | 0 | 0
25 | Non-Riverine Wetlands and Associate | 0 | 0 | 0 | 0.00 | 0 | 0 | 0
26 | Cliffs (White Bluffs) | 0 | 0 | 0 | 0.00 | 0 | 0 | 0
HSI
Microsoft Excel - HER...


Microsoft Excel - HERMES.MOD
Cover Class
Area
Description
Mit Cost
Species Value
Other Value
Total Value
1 26 Post-fire shrub-steppe on the Columbia River Plain $78,000 7188 $85,188
4 17 Big Sagebrush/ Bunchgrasses-Cheatgrass $68,000 9376 $77,376
5 0 Big Sagebrush-Spiny Hopsage/ Bunchgrasses-Cheatgrass $0 0 $0
14 92 Cheatgrass-Sandberg's Bluegrass $0 2368 $2,368
23 0 Buildings/ Parking Lots/ Gravel Pits/ Disturbed Areas $0 0 $0
Total Cost $146,000 $18,932 $0 $164,932
....would reduce the shrike population size, and therefore, reduce the overall species value estimate.

HERMES Extensions

- One extension allows user to compare ecological impacts of alternative burial sites for waste site remediation projects
- HERMES estimates the area requirement for specified amounts of material and depth of proposed burial ground
- Side slopes and spoils storage areas taken into account

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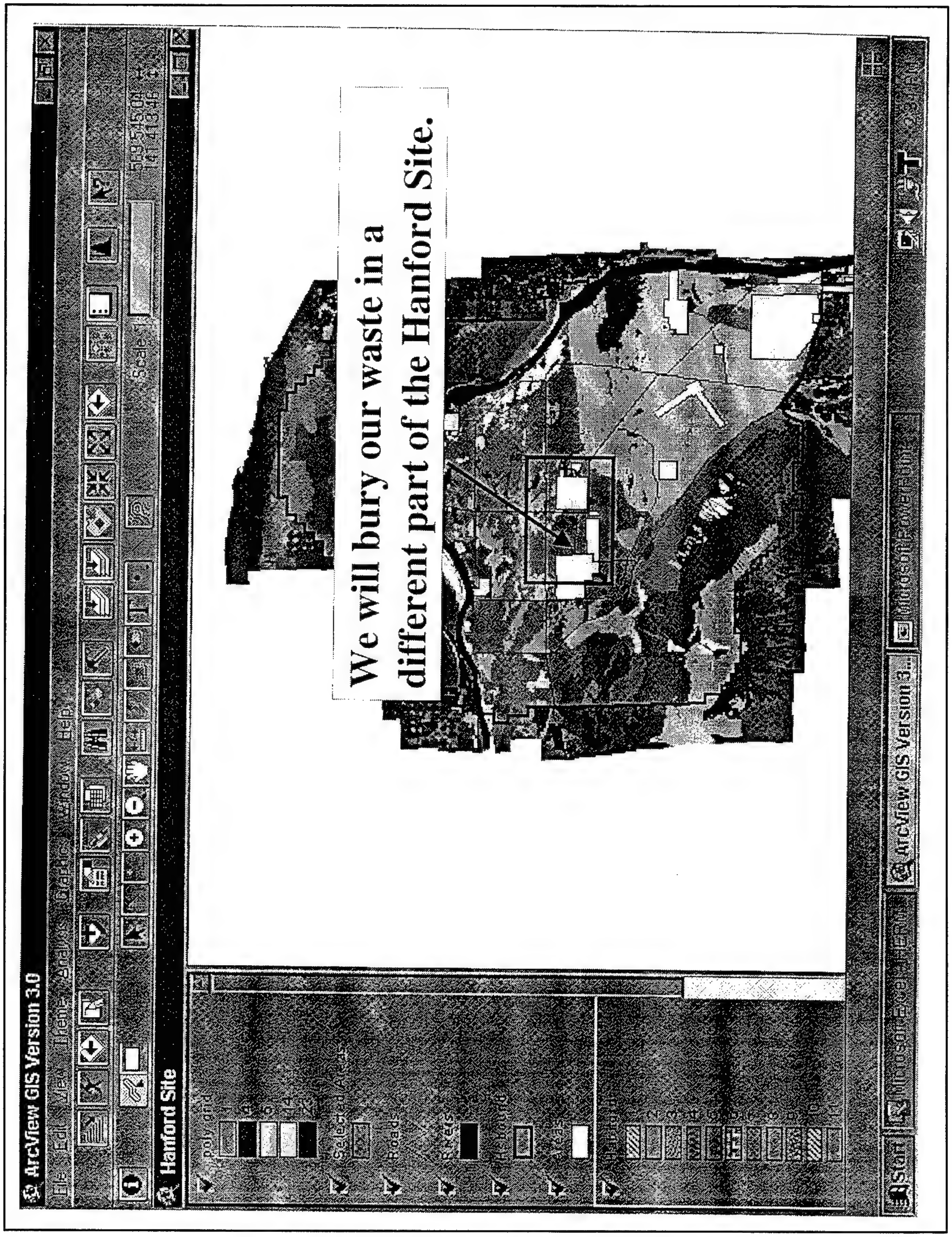
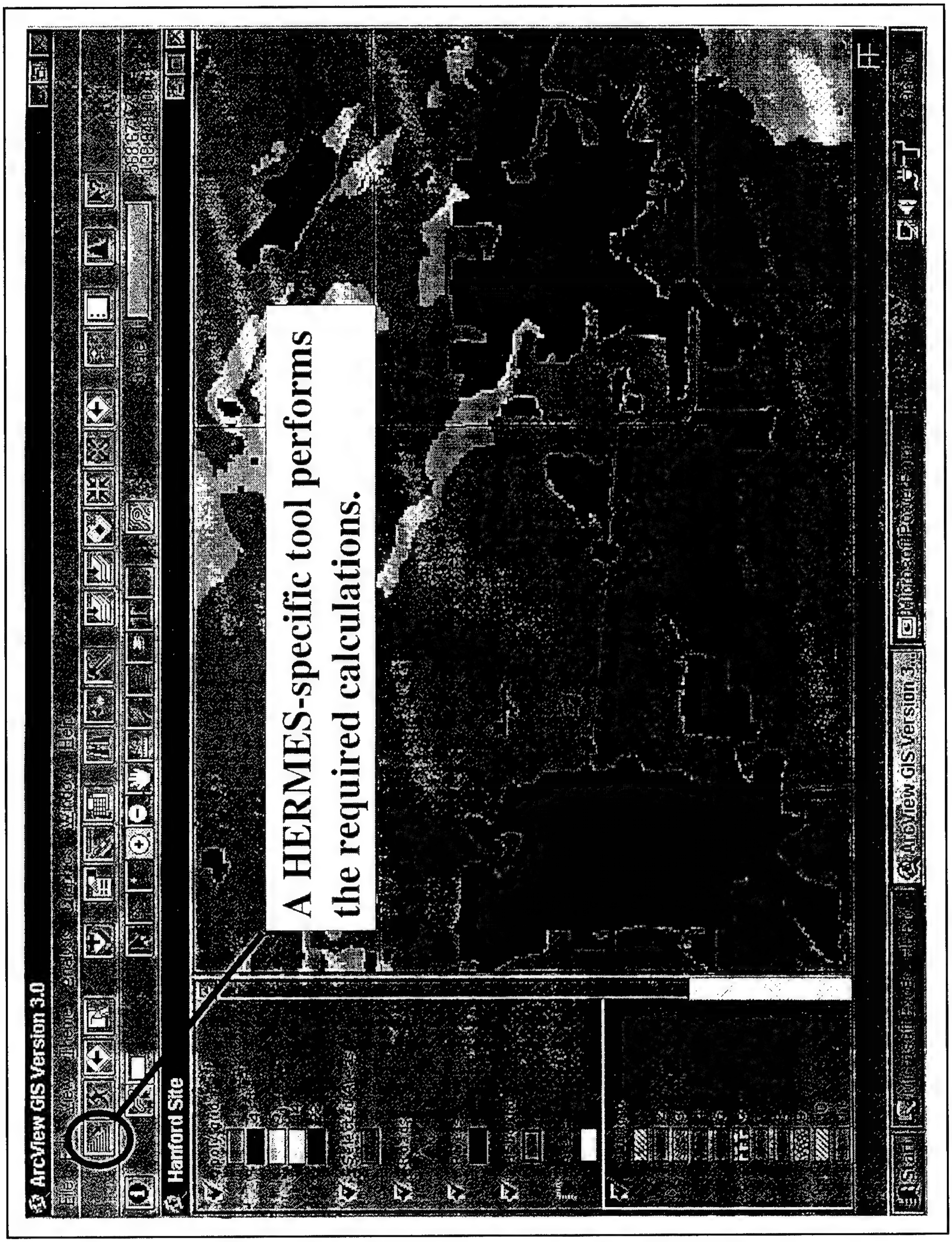
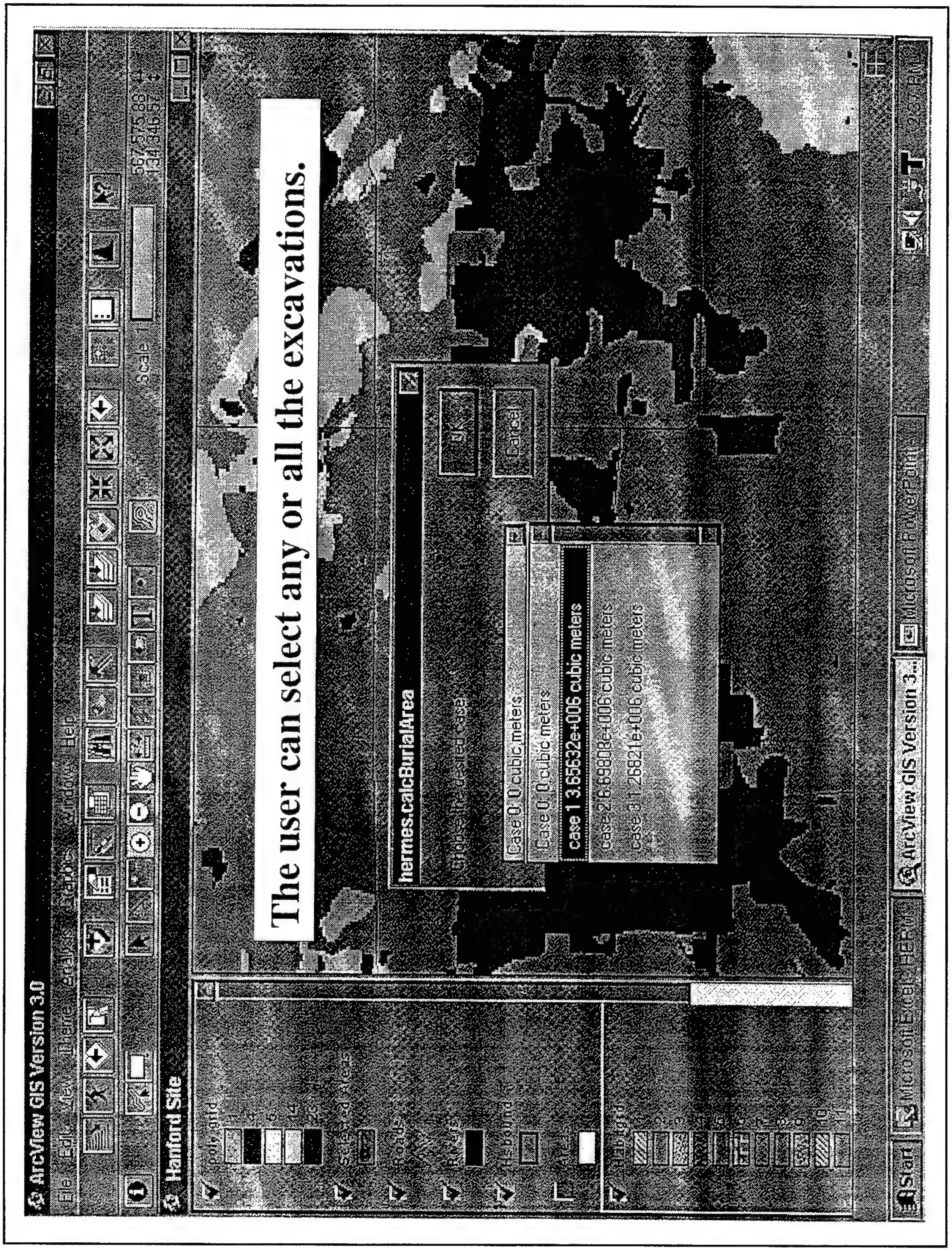
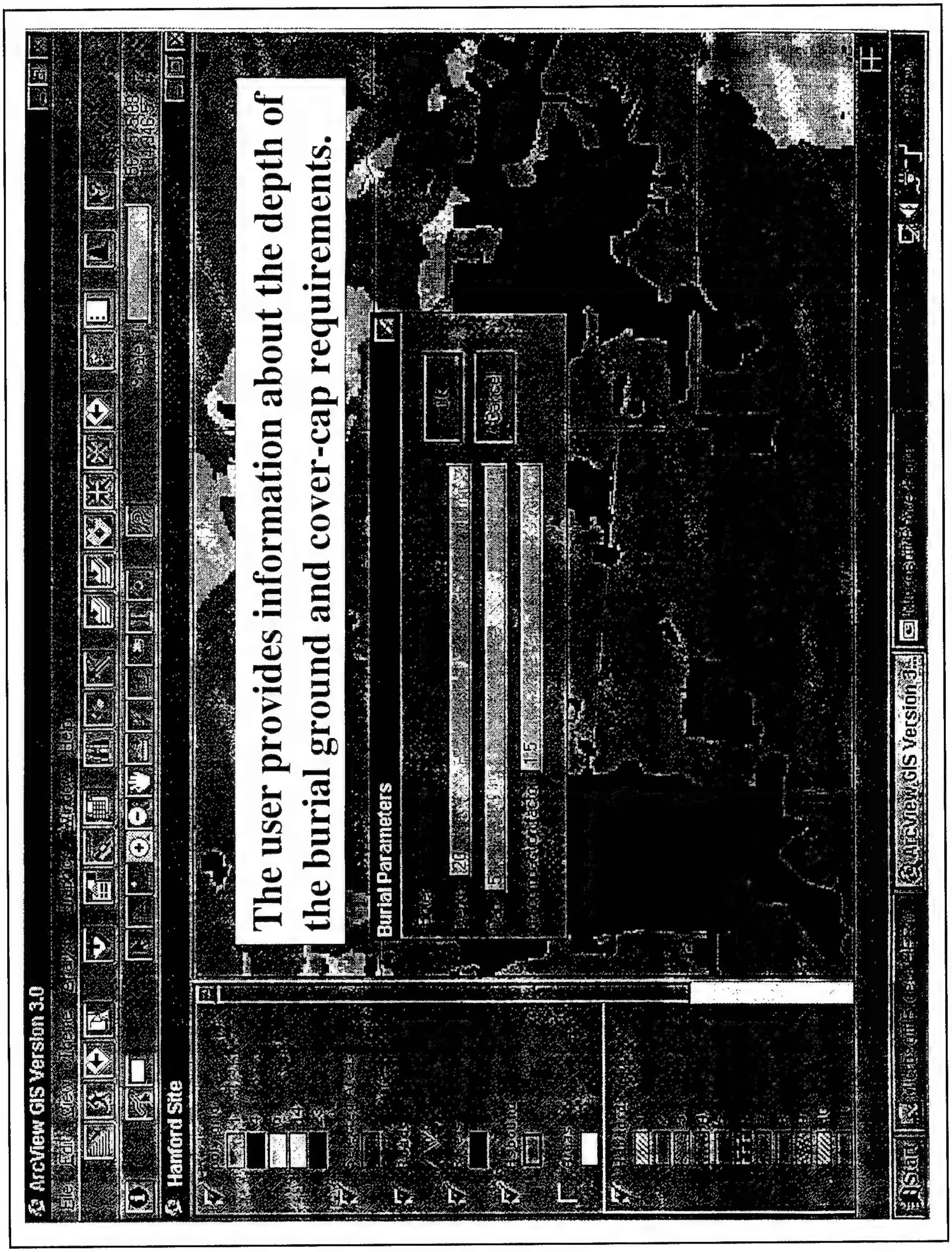
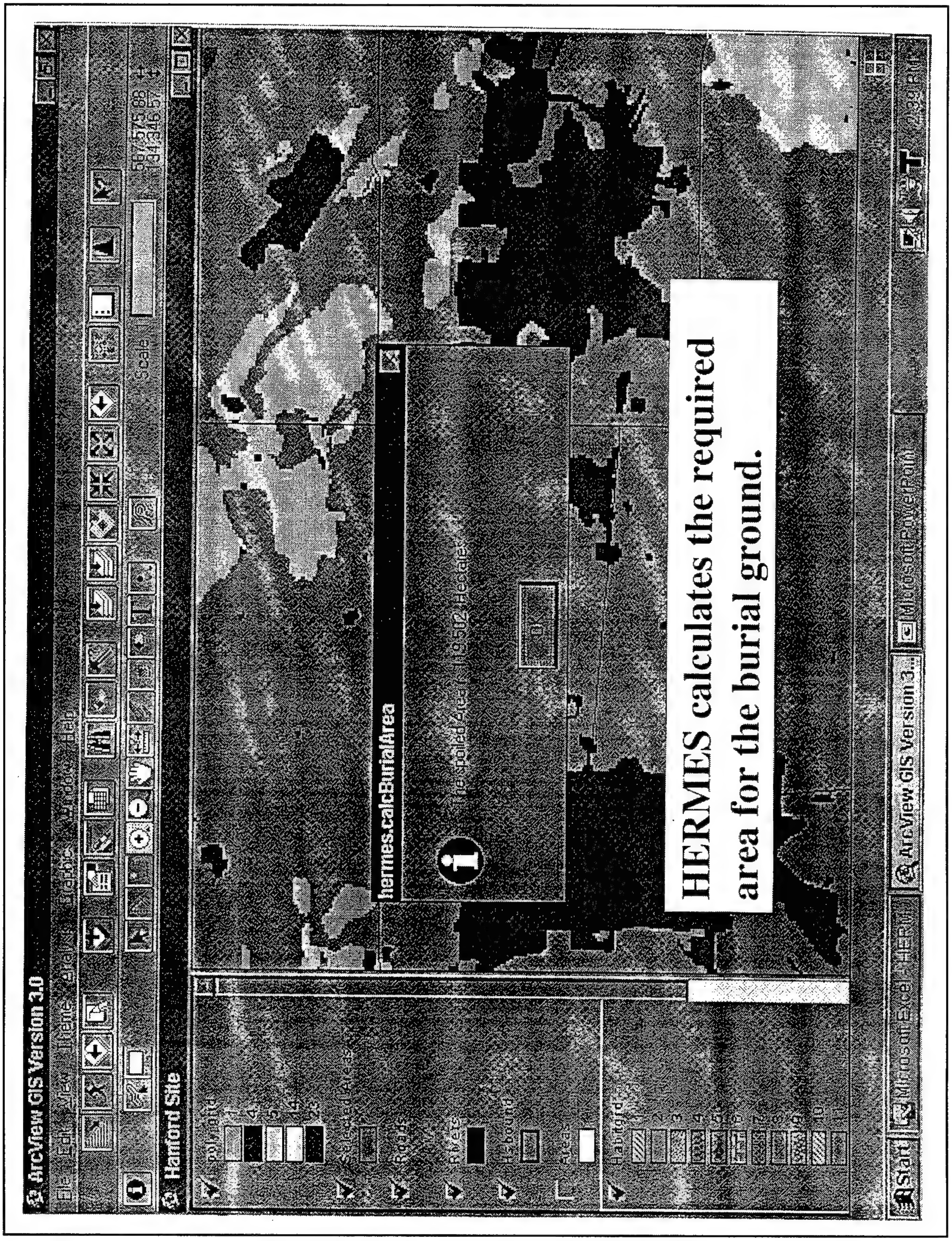

ArcView GIS Version 3.0
Hanford Site
We will bury our waste in a
different part of the Hanford Site.
ArcView GIS Version 3...

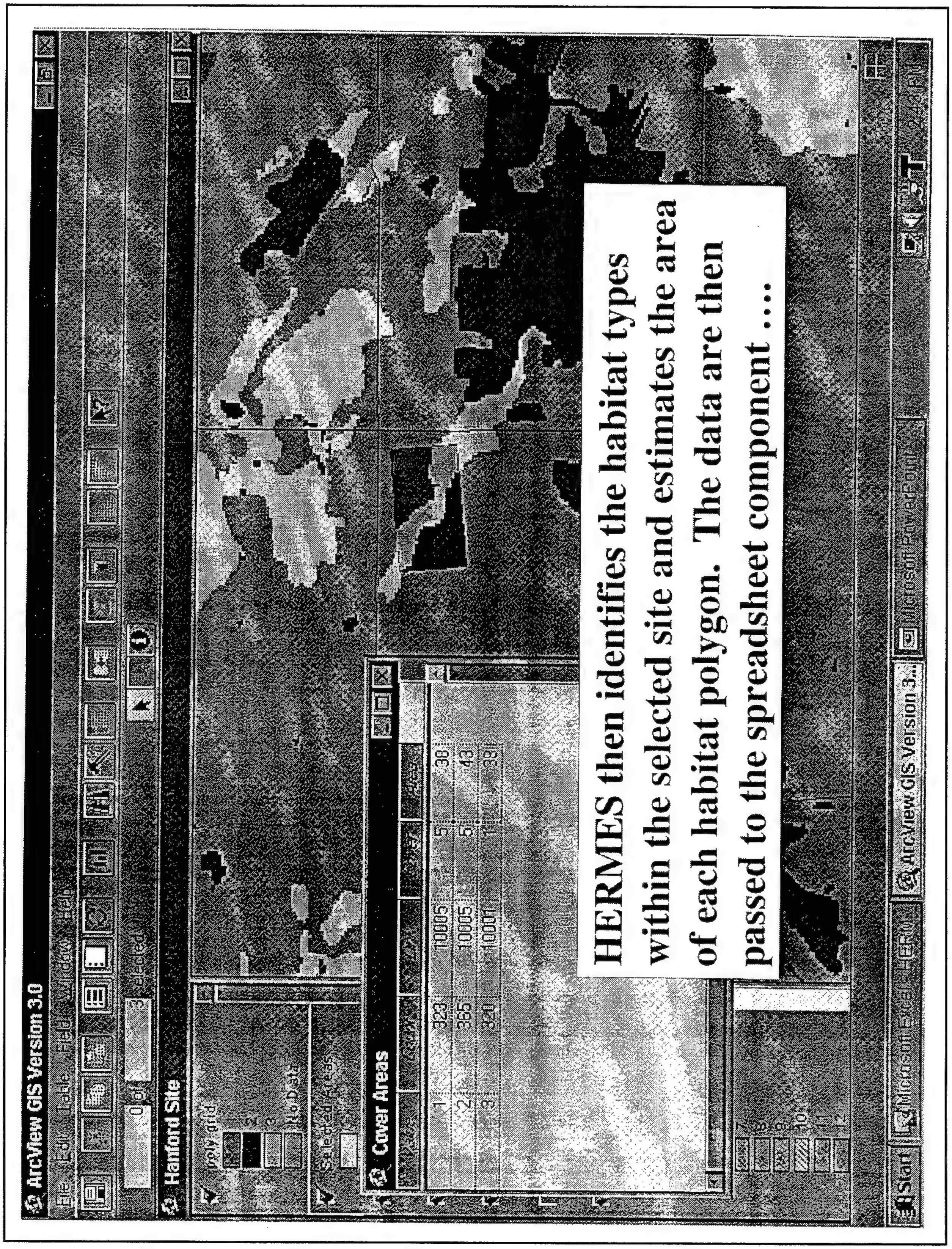

ArcView GIS Version 3.0
Hanford Site
A HERMES-specific tool performs the required calculations.
ArcView GIS Version 3.0

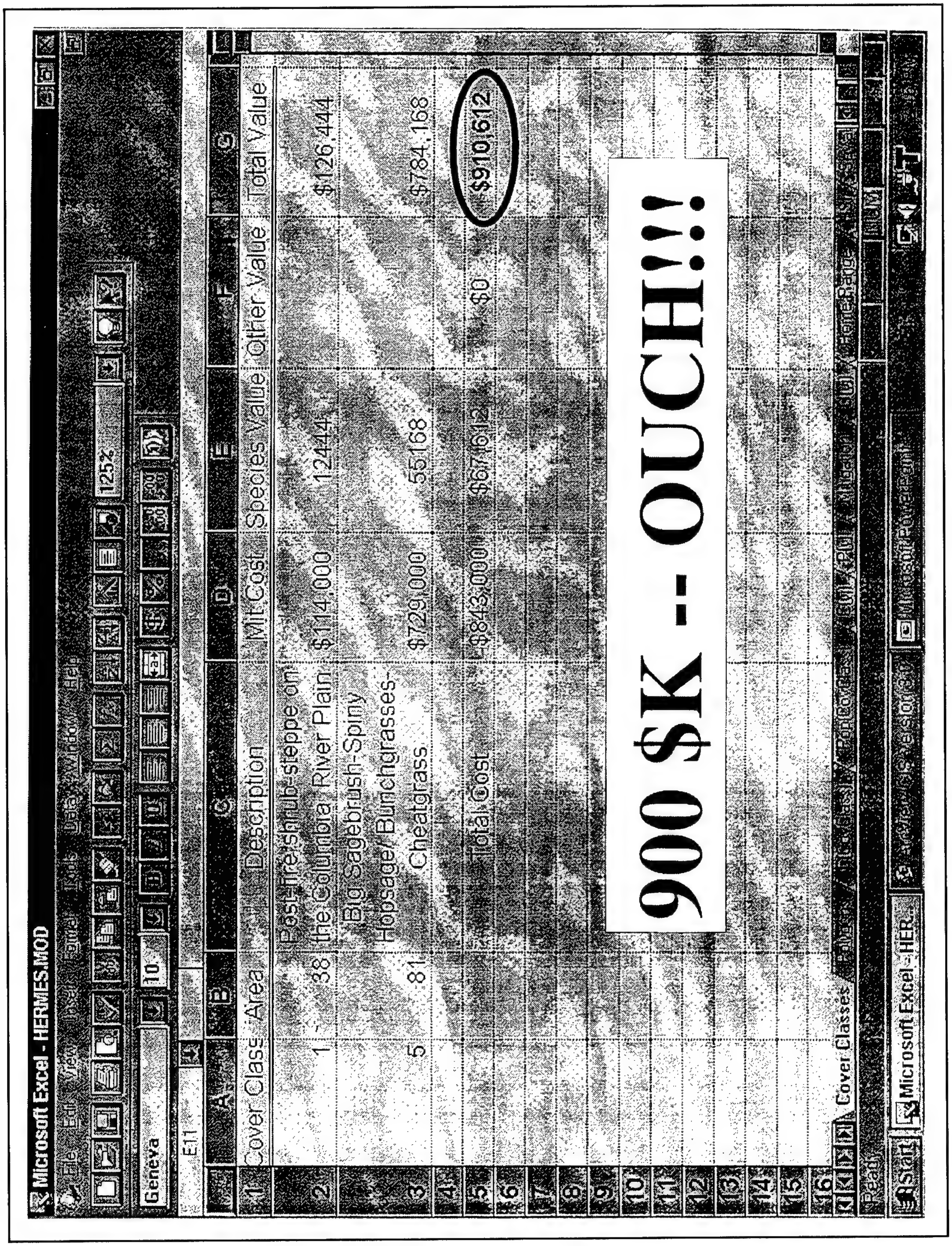

The user can select any or all the excavations.
ArcView GIS Version 3.0
Hanford Site
hermes.calcBurialArea
case 1 3.65632e+006 cubic meters

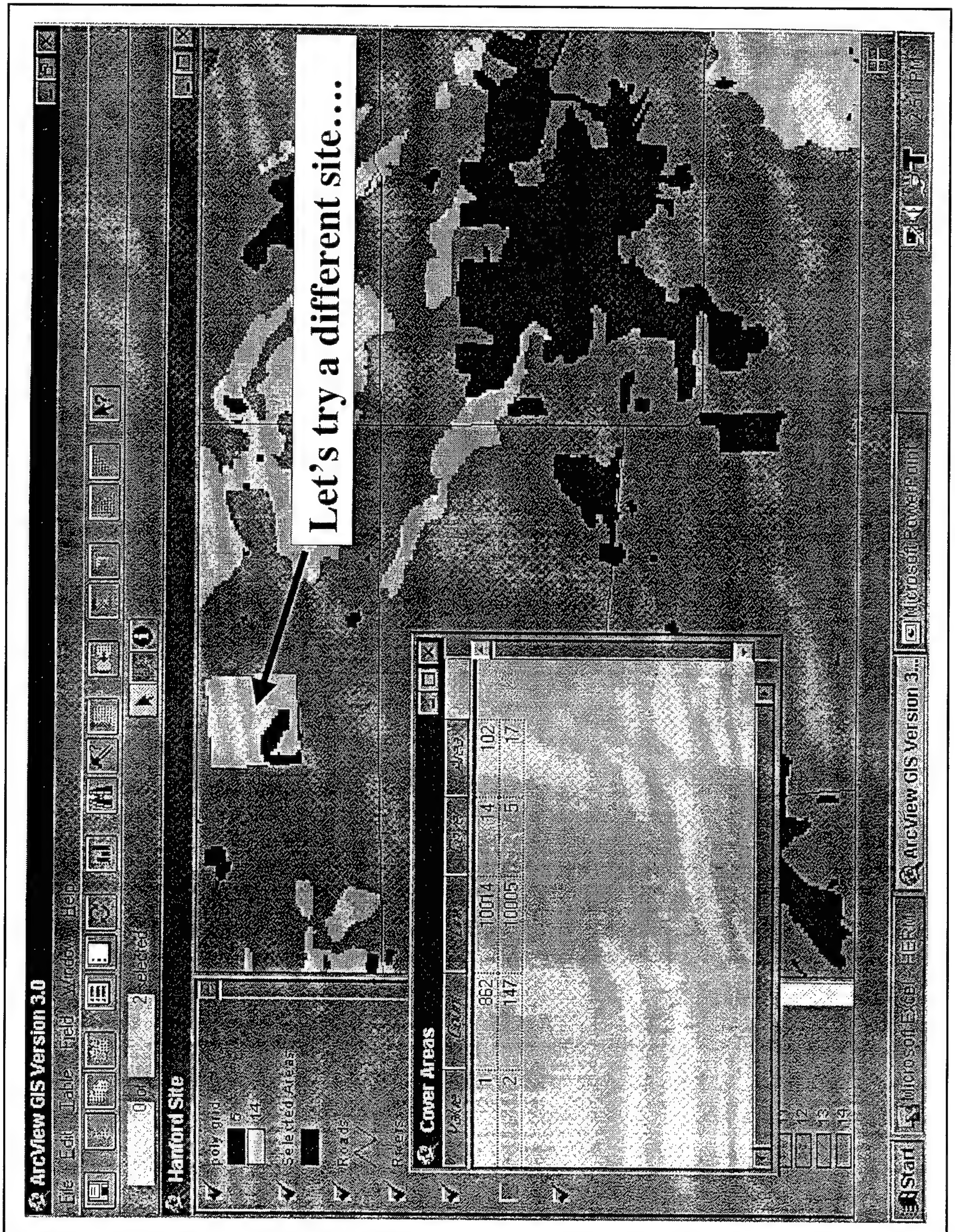

ArcView GIS Version 3.0
Hanford Site
The user provides information about the depth of the burial ground and cover-cap requirements.
Burial Parameters
ArcView GIS Version 3.0

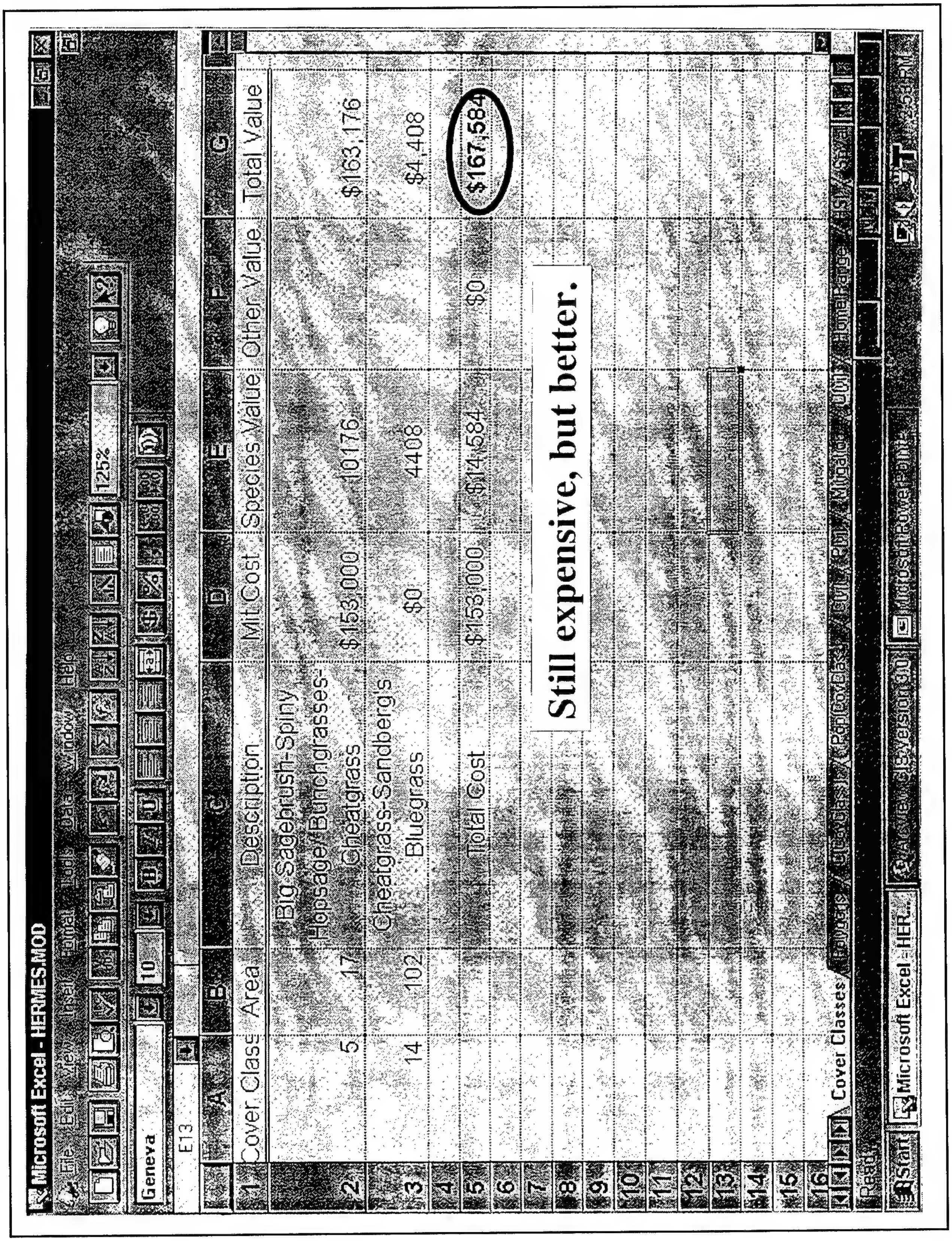

ArcView GIS Version 3.0
Hanford Site
hermes.calcBurialArea
HERMES calculates the required area for the burial ground.


ArcView GIS Version 3.0
Hanford Site
The user selects a burial ground location and draws one side. HERMES automatically calculates the other dimension.
ArcView GIS Version 3.0


ArcView GIS Version 3.0
Hanford Site
Cover Areas
HERMES then identifies the habitat types within the selected site and estimates the area of each habitat polygon. The data are then passed to the spreadsheet component ....


Microsoft Excel - HERMES.MOD
Cover Class
Area
Description
Mit Cost
Species Value
Other Value
Total Value
1
38
Post-fire shrub-steppe on the Columbia River Plain
$114,000
12444
$126,444
5
81
Big Sagebrush-Spiny Hopsage/Bunchgrasses-Cheatgrass
$729,000
55168
$784,168
Total Cost
$843,000
$67,612
$0
$910,612
900 $K -- OUCH!!!
Cover Classes
Microsoft Excel - HER...


ArcView GIS Version 3.0
Hanford Site
Cover Areas
Let's try a different site.....


Microsoft Excel - HERMES.MOD
Cover Class
Area
Description
Mit Cost
Species Value
Other Value
Total Value
5
17
Big Sagebrush-Spiny Hopsage/Bunchgrasses-Cheatgrass
$153,000
10176
$163,176
14
102
Cheatgrass-Sandberg's Bluegrass
$0
4408
$4,408
Total Cost
$153,000
$14,584
$0
$167,584
Still expensive, but better.
Cover Classes

Potential Extensions

- Analyze habitat value rather than $$ value
- Restore site to any user-selected cover type, regardless of original cover type
- Calculate borrow site dimensions and associated ecological costs
- Calculate engineering costs for infrastructure development (i.e., roads, utilities)
- Include cultural resource concerns

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Use in Risk Assessment

- Exploring integrating HERMES and MEPAS within FRAMES to allow for spatial assessment of ecological/human health risk
- MEPAS would provide spatial grid of contaminant concentrations
- HERMES would provide the area of each habitat type at each concentration level

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Use in Risk Assessment - cont'd

- Output of MEPAS/HERMES integration will be used to predict potentially affected species and the number of affected individuals at each concentration level
- Predict changes in habitat value over time due to the contaminants
- Mitigation decisions could be based on habitat value rather than cost-to-replace

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Requirements for Adaptation of HERMES to Other Settings

- Rastorized GIS map of habitat/cover types
- Site-specific framework for habitat restoration / mitigation decision making
- Estimates of costs to perform actions
- List of indicator species
- Estimates of home range and habitat suitability matrix for each species

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Summary

- Phased Approach
- FRAMES as an Integrating Platform
- Linkages Between Fate & Transport, Ecological, and Human-Health Models

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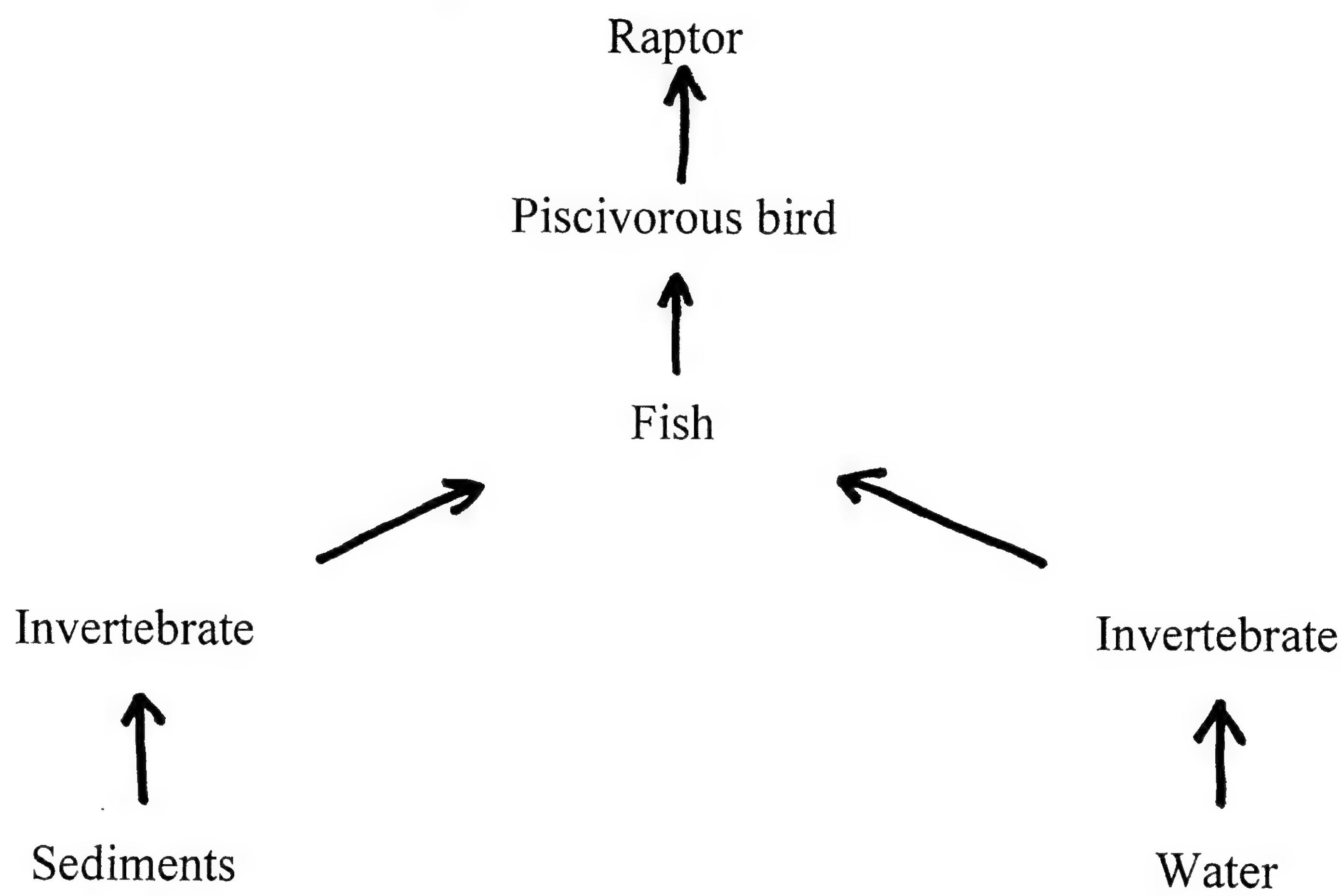
Appendix K
Exposure Assessment - Trophic Transfer to Birds

This appendix contains the presentation documents for "Exposure Assessment - Trophic Transfer to Birds" by David Glaser - Quantitative Environmental Analysis.

Quantitative Environmental Analysis, LLC

Exposure Assessment - Trophic Transfer to Birds

David Glaser
Quantitative Environmental Analysis, LLC.
Montvale, New Jersey



-2-

Quantitative Environmental Analysis, LLC.

1. Why quantify trophic transfer to birds?

-3- Quantitative Environmental Analysis, LLC.

- to compute contaminant levels in species of interest

Bald eagles in the Southern California Bight

Prey		
Species	% of Diet	Measured DDE Conc. (whole body)
Fish + invertebrates	86	0.11
Sea lions	2.7	26.
Western gulls	2.6	8.3
Other gulls	0.9	5.4
Water birds	6.2	1.7
Land birds	0.9	1.4

→

Bald eagle
Computed DDE Conc. (eggs)
37

Contaminant levels can be used to assess the potential for toxicity.

- to establish pathways of contamination

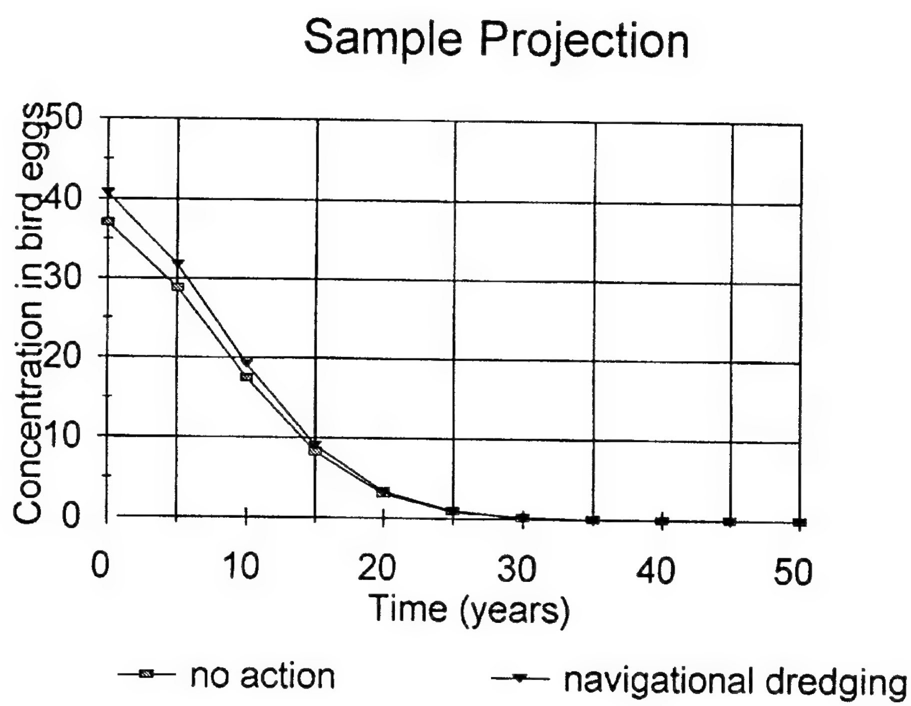
Bald eagles in the Southern California Bight

Prey		
Species	% of Diet	Measured DDE Conc.
Fish + invertebrates	86	0.11
Sea lions	2.7	26.
Western gulls	2.6	8.3
Other gulls	0.9	5.4
Water birds	6.2	1.7
Land birds	0.9	1.4

→

Bald eagle	
Computed DDE Conc.	Measured DDE Conc.
37	36 (27-45)

- to project future concentrations



-6-

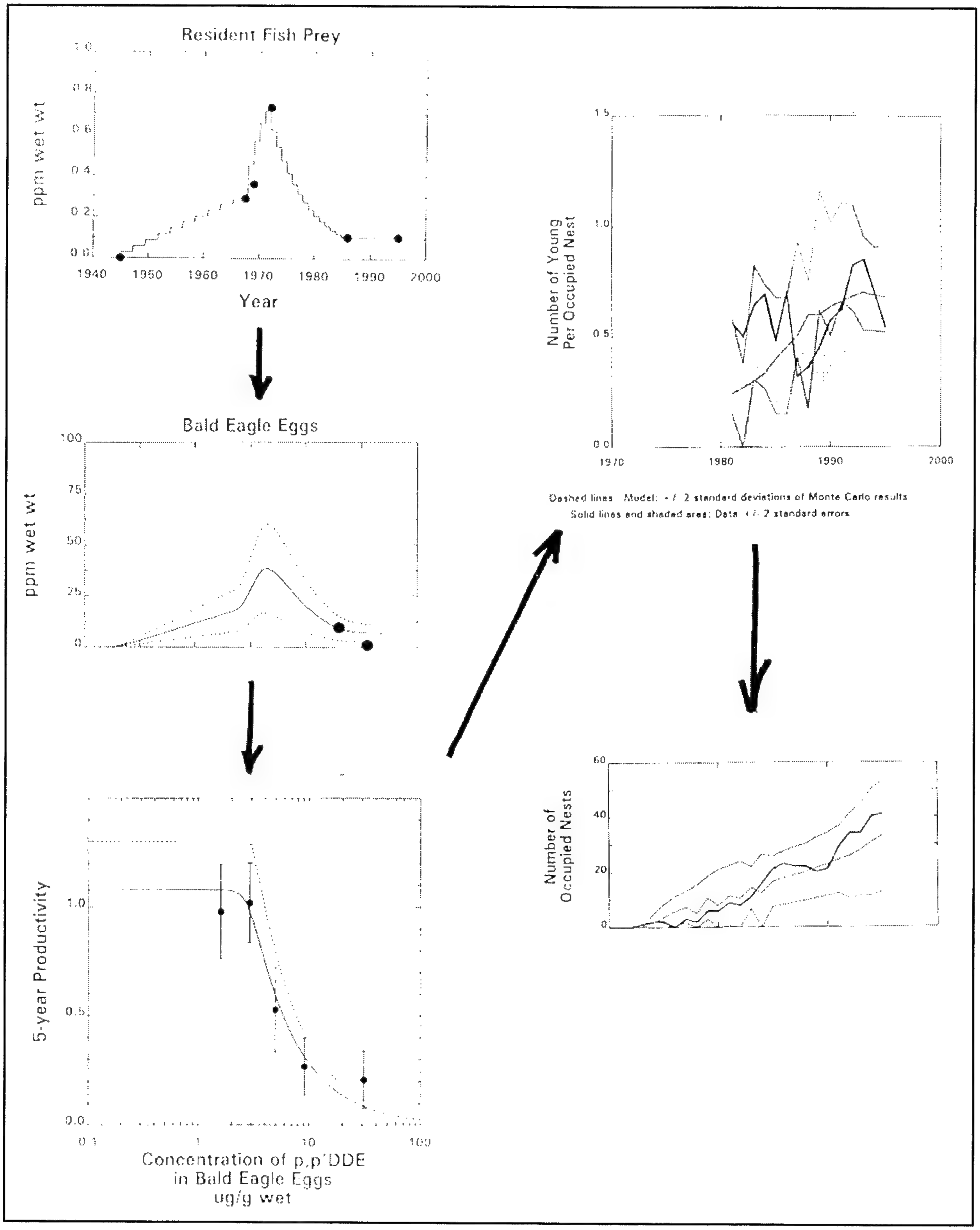
Quantitative Environmental Analysis, LLC.

- to estimate the potential for effects on population dynamics

	Bioaccumulation Analysis		*Conc./Response Relationship*		*Pop. dynamics model*	
Exposure Conc.	→	Conc. in birds	→	Impact on reproduction or survival	→	Impact on pop. dynamics

-7-

Quantitative Environmental Analysis, LLC.



Resident Fish Prey
ppm wet wt
Year
Bald Eagle Eggs
ppm wet wt
5-year Productivity
Concentration of p,p'DDE in Bald Eagle Eggs ug/g wet
Number of Young Per Occupied Nest
Dashed lines: Model: +/- 2 standard deviations of Monte Carlo results
Solid lines and shaded area: Data +/- 2 standard errors
Number of Occupied Nests

Bioaccumulation can be computed in several ways:

- Trophic transfer ratios, bioaccumulation factors

Ratios of DDE Levels in the Eggs of Predatory and Piscivorous Birds and Their Prey

Species	Weight (kg)	Prey	Source of Birds (study duration)	Movement	Ratio Between Compartments	Age of Egg	Reference
Peregrine Falcon	1.0	Birds	Yukon River, AK	migratory	16	unknown	Cade et al. 1968
Peregrine Falcon	1.0	Birds	Rocky Mountains, CO, AZ and NM	at least weakly migratory	23	addled eggs; variable age	Enderson et al. 1982
Peregrine Falcon	1.0	Birds	Rocky Mountains, CO, AZ and NM	migratory	6.8	addled eggs; reported ppm dry with percent water factor	Ellis et al. 1989
Bald Eagle	4.5	Birds	Klamath Basin, OR	resident	47	variable - corrected to fresh	Frenzel 1985
Double-crested Cormorant	2.1	Fish	Lake Huron	migratory	57	fresh	Weseloh et al. 1983

Notes: Wet weight basis
w.b. = whole body

- Steady-state model

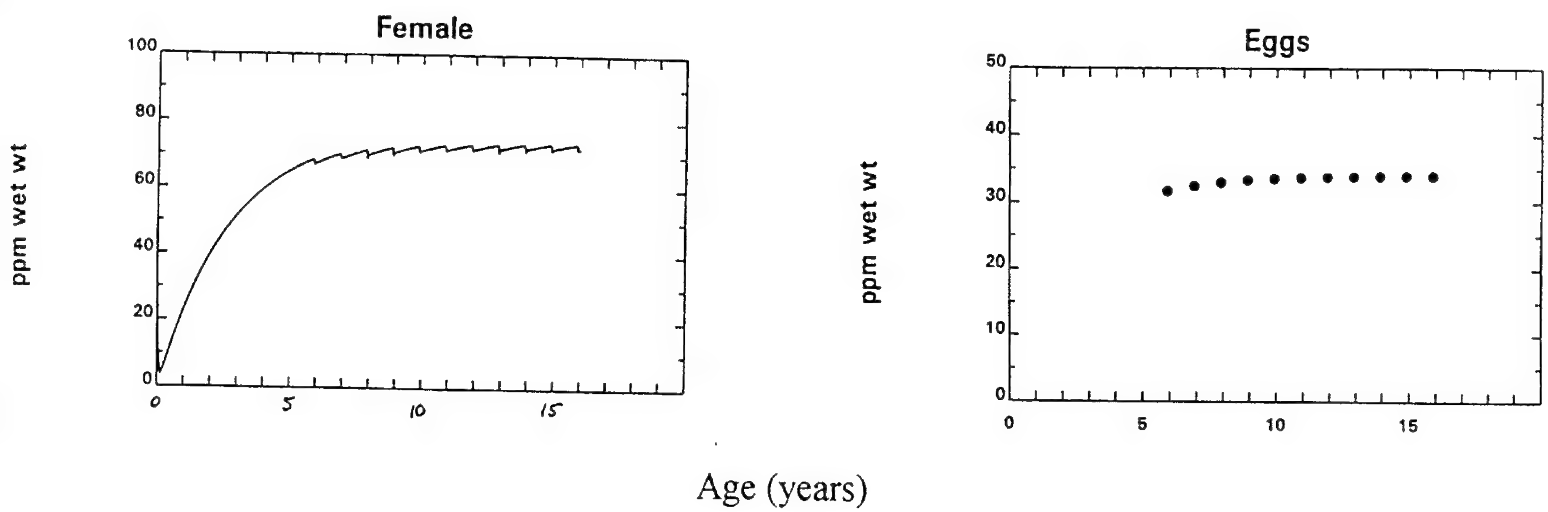
Great Lakes Initiative

$$WV = \frac{TD}{F \times BAF} \times \frac{1}{UF} \tag{1}$$

WV = wildlife water quality value (pg/L)
TD = toxic dose (mg/kg-day)
UF = uncertainty factor
F = food ingestion rate (kg/kg-day)
BAF = bioaccumulation factor (L/kg wet weight)

- Time-variable simulation model

$$\frac{dc}{dt} = \alpha C c_p - Kc - Ec$$



Concentration of p,p'DDE in a female bald eagle and in her eggs

-12- Quantitative Environmental Analysis, LLC.

Strengths

BAFs →	Steady-state model →	Time-variable model →	Calibrated model
Simplicity	Species-specific parameterization Included	Changes in relative importance of sources can be evaluated	Reduced uncertainty
species-specific food web, bioenergetics, migration, foraging behavior, life-cycle accumulation, temporal changes in exposure sources and levels	life-cycle accumulation, temporal changes in exposure sources and levels	Requires modeling capability and information on parameters	Requires site-specific data

Limitations

UNCERTAINTY DECREASES →

-13-

Quantitative Environmental Analysis, LLC.

Uncertainty

- Uncertainty analysis for calibrated and uncalibrated models differ.
- Calibration reduces uncertainty by restricting the parameter sets that are consistent with field measurements.

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14. ABSTRACT

The Fate & Effects Advisory Committee (FEAC) identified the need for the development of models capable of providing information relating to the fate and effects of Military Relevant Compounds (MRCs) on both ecological and human resources. Requirements for better modeling capabilities of contaminant concentration over time for risk assessment were stated. In an effort to address the requirement, a work unit was initiated for the development of an Army Risk Assessment Modeling System (ARAMS). This system will incorporate other research efforts conducted in the Fate & Effects Research Program and will enable thorough evaluation of ecological and human risk assessments.

The ARAMS will be developed for the purpose of conducting ecological and human risk assessments. Development of this system will incorporate current state-of-the-art modeling technologies and will further utilize concurrent research efforts in the Fate and Effects Research Program. ARAMS is a tool to characterize, integrate, and estimate ecological risk. The system will provide several tiers of complexity such that screening-level and complex model issues can be addressed. The system will include: (a) screening-level assessments based on simple exposure-response relationships and limited spatial and temporal scales, (b) an expanded assessment

(continued)

15. SUBJECT TERMS
ARAMS, Ecological and human health, Fate and effects, Risk assessment

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14. ABSTRACT (Concluded)

capability based on linkage of more rigorous exposure and ecological assessment techniques, and (c) linkage of ecological risk, comprehensive exposure models, and integrated temporal-spatial exposure, . . . i.e., probabilistic estimate of exposure for individuals/population in time and space.

The objective of this workshop was to ascertain the current state of the art in risk assessment modeling and to facilitate discussion of the components required for an ARAMS.

The development of ARAMS is anticipated to take several years to complete. One last major point discussed at the workshop was the necessity of choosing a proper location to test the system. A site would have to be chosen with a plethora of data such that screening- and comprehensive-level approaches for risk assessment for both ecological and human risk could be validated.